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Water Management at a Barley Brewery

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by

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SYNOPSIS

In order to manage and reduce water usage at traditionally high percentage water users like breweries, it is essential that comprehensive water balances be available to base educated decisions upon. In this thesis a water management investigation at the South African Breweries Rosslyn plant was completed to develop a suitable water balance for the plant. Literature studies, plant trials, analysis of historic and current plant data and consultations with brewery personnel were among the diagnostics used in the investigation. Detailed water balances were compiled for each process within the brewhouse, the cellars, packaging hall and general site water. (Schematic water flow diagrams were drawn up for each of these unit processes, culminating in an overall water balance for the plant.) Based on the overall water balance, it was found that 5 m^3 of water was utilised to produce 1 m^3 of beer at the Rosslyn plant.

Since the treatment and disposal of effluent forms a significant cost of production and their significance bound to increase, breweries need to optimise water usage at their relevant sites. The thesis also identified many opportunities to minimise water intake at the Rosslyn plant, and therefore effluent generated. All opportunities such identified should be consolidated into an integrated water management system to optimise water usage at the plant.

KEYWORDS : water management, barley brewery, water usage, water balance

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CHAPTER 1

INTRODUCTION

The production of beer involves the blending of the extracts of malt, hops and sugar with water, followed by its subsequent fermentation with yeast. The brewing industry employs a number of batch-type operations in processing raw materials to the final beer product. In the process, large quantities of water are used for the production of beer itself, as well as for washing, cleaning and sterilising of various units after each batch is completed. A large amount of this water is discharged to the drains.

For many years the brewing industry has recorded high ratios of water used to beer produced. This can be as high as 10:1 in sites with large smallpack production, and as low as 5:1 on some traditional brewing sites (Crispin, 1996). The main water usage areas of a typical brewery are brewhouse, cellars, packaging hall and general water use. Water use attributed to these areas includes all water used in the product, vessel washing, general washing and cleaning in place (CIP); which are of considerable importance both in terms of water intake and effluent produced.

With rising water prices and ever increasing competitiveness within the marketplace, the importance of raw material costs, including water, in determining product costs and profitability should not be ignored. The minimisation of water costs should be given a high priority since it is an area where the consumption (and generation in the case of effluent) is directly under the control of the brewery site (Barnard and Alexander, 1996).

Over the last three decades many papers dealing with all aspects of malt, hops, sugar and yeast can be sourced. However, very little technical literature relates to the minimisation of water used on a brewery site. Since breweries are understanding the necessity of managing water utilised by their relevant sites, a detailed water management investigation, orientated towards those processes producing waste and effluent, needs to be undertaken. This will enable a thorough assessment of the steps that can be introduced to minimise waste volumes and strengths, and hence effluent treatment requirements. Detailed factory investigations are often costly exercises, although the costs are recovered many fold by savings in raw water, raw materials, water treatment and/or effluent treatment costs (Barnard and Alexander, 1996).

In this thesis a detailed water management investigation will be conducted on the Rosslyn brewery site. Information regarding the assessment of water management in the various brewing sections will be sourced from :

- literature,
- plant trials,
- historic analysis,
- supplier documentation and consultation and
- personal communication.

In Chapter 2, a literature survey outlining the brewing and packaging process will be addressed. The theoretical development in Chapter 2 forms the framework for development of mass balances presented in Chapter 3 to 6, which will address the following:

- water usage in the brewhouse (Chapter 3),
- water usage in the cellars (Chapter 4),
- water usage in the packaging hall (Chapter 5),
- general water usage (Chapter 6), and
- overall consolidated water balance (Chapter 6).

Finally, in Chapter 7 conclusions and recommendations based on this water management investigation are given to optimise present operations at the plant.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION AND BACKGROUND

South African Breweries (SAB) is the biggest producer of malted barley beer in South Africa with subsequent large amounts of water used in the process. An investigation by Binnie and Partners (1986), with respect to the water consumption for SAB breweries in South Africa, yielded the results shown in Table 2.1. For these breweries the volume of water used per volume of beer produced (excluding malting plants) ranges from 5,5 – 8,8 m^3 water/m^3 beer.

Table 2.1 The ratio of water used (excluding malting) per beer product produced for different breweries in South Africa.

Brewery	Average beer production per month in m^3	Average water intake per month in m^3	Water used per beer product in m^3/m^3
A	17 100	102 500	6,0
B	9 000	79 100	8,8
C	18 200	129 000	7,1
D	14 000	77 000	5,5
E	2 000	13 700	6,8
F	16 000	100 800	6,3
G	8 300	61 700	7,4
H	5 200	34 700	6,7

Since environmental legislation is becoming more stringent, it will become necessary for brewing industries to manage the consumption of water in breweries and therefore the reduction of effluent. This may be accomplished by developing environmental management tools to monitor water usage and developing recycling techniques to optimise the usage of water. With limited or no information/benchmarks available in the literature pertaining to water consumption in breweries, a detailed investigation into the brewing process needs to be undertaken to determine why:

- brewing industries consume such high volumes of water, and
- why there is significant differences in the water to beer ratio for breweries producing approximately the same volumes of beer.

2.2 BEER COMPOSITION AND PRODUCTION

Hulse (2000) gives two definitions for beer, namely

- it is a liquid extract of malted barley which has been flavoured with hops and fermented with yeast, and/or
- beer is a carbonated, weakly alcoholic beverage which is prepared from malt, hops, water and yeast.

The essential elements of a beer are, *inter alia*, the aroma, taste, colour, foam and alcohol content. Beers differ in these characteristics due to the type of ingredients used (for example, sorghum or barley) and/or different operating parameters. In South Africa, the majority of breweries use malted barley and this document will thus concentrate on the water use within the malted barley production process. A generalisation by Wainwright (1998) of beer production is shown in Figure 2.1.

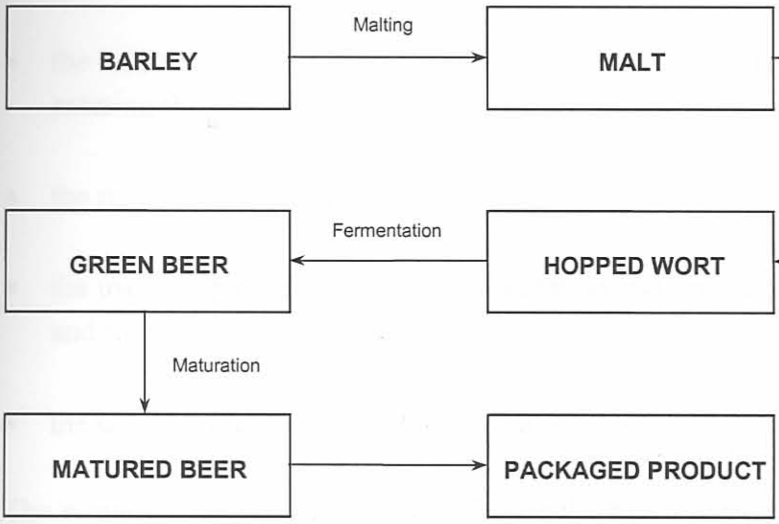


Figure 2.1 Basic overview for the production of beer.

This simplified process diagram is typical for most breweries and the process starts off with the malting of barley. Malting is the process whereby barley kernels (also termed grains or corns) are germinated for a limited period of time and then dried. The malted barley kernels, which are termed malt, are then milled to expose the endosperm (which is the part of the barley kernel which contains most of the food reserves/starch). The milled malt is then mashed in a vessel called the mash tun. Mashing is the process whereby the starch is extracted from the malt, with the addition of water, to produce sweet wort. The enzymes developed during the malting process are released during mashing and convert the exposed starch to fermentable sugars. Malted barley converted into a product with the correct amount of fermentable sugars, nitrogen compounds and other essential components, is termed wort. In order to remove volatile compounds from the wort and to add the bitter flavour characteristic of a beer, the wort is boiled with hops in a vessel termed the wort kettle. This hopped wort is then fermented with yeast in fermentation vessels where the sugars are converted to alcohol and CO_2 and the subsequent product is termed green beer. The green beer is transferred to storage vessels for at least a week to mature the beer. Thereafter the beer is filtered and forwarded to the packaging production line.

2.3 PRODUCTION OF MALTED BARLEY BEER

A typical malted barley beer brewing process is presented in Figure 2.2 by the Pollution Research Group (1987). Malted barley breweries are divided into four hypothetical areas, namely malting, brewhouse, cellars (fermentation and filtration) and packaging. A similar brewing process is employed by SA Breweries at their Rosslyn plant with a few exceptions, as depicted in Figure 2.3. These include, *inter alia*,

- the removal of the maize cooker, where maize was added to the brewing process,
- the addition of a buffering vessel, called the underback, where the wort is placed before entering the wort kettle,
- the removal of the hop strainer (all waste is removed in the whirlpool) and the wort filter,
- the use of separate vessels for fermentation and primary storage prior to the maturation phase, and finally
- the use of a filter prior to the maturation phase.

The remainder of this chapter will discuss the brewing processes utilised in the four hypothetical areas, as practised at the SAB Rosslyn plant.

2.3.1 Malting

The first stage of malting is termed steeping (see Figure 2.3). During steeping barley kernels are soaked in water until they contain 42 – 44 % moisture required for embryo growth (the embryos are contained within the barley kernels) and adequately supplied with oxygen (Kunze, 1999). Water uptake by the barley kernels depends on, *inter alia,* the steeping time, steeping temperature and barley kernel size.

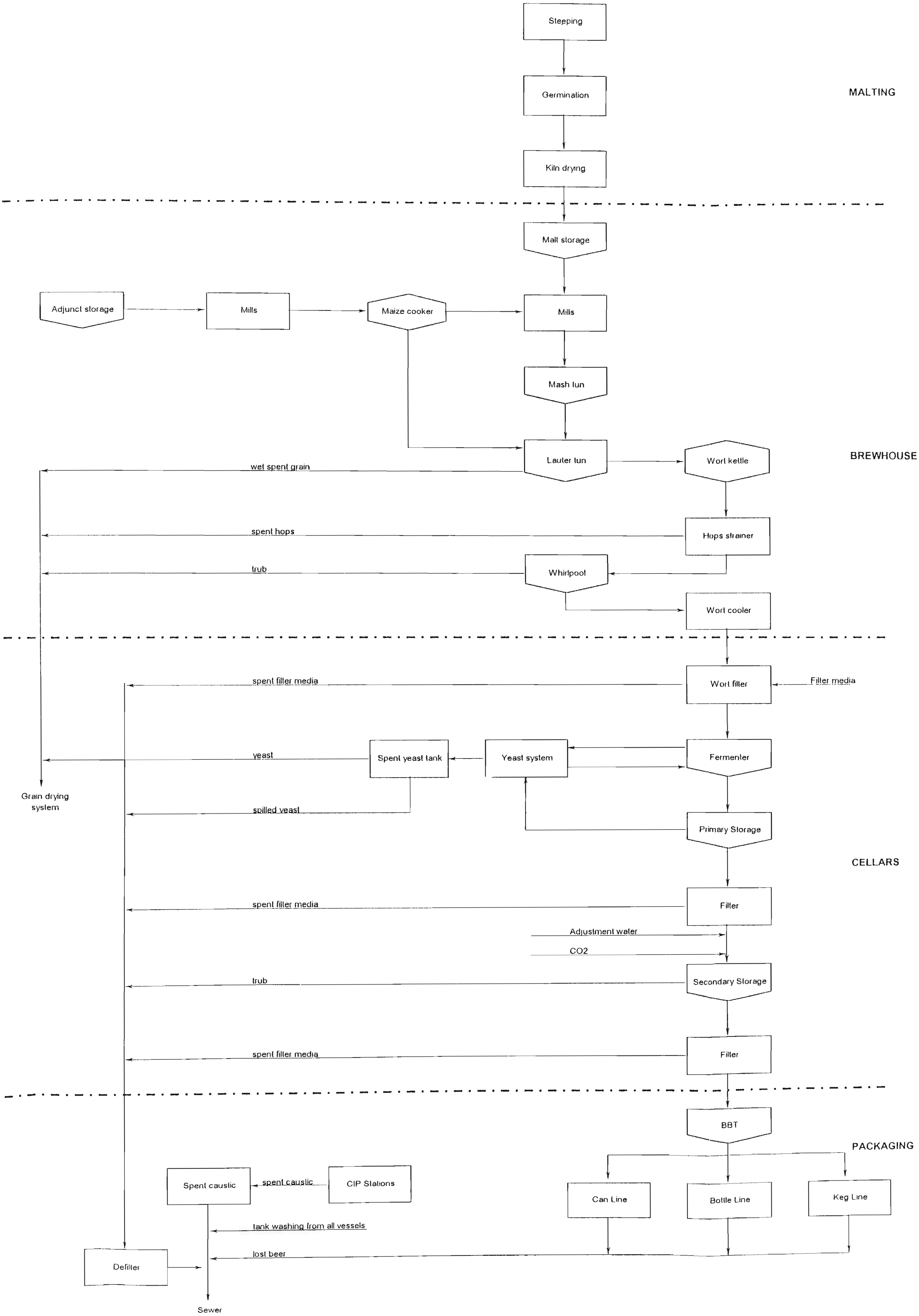


Figure 2.2 A typical process flow diagram of a barley brewery

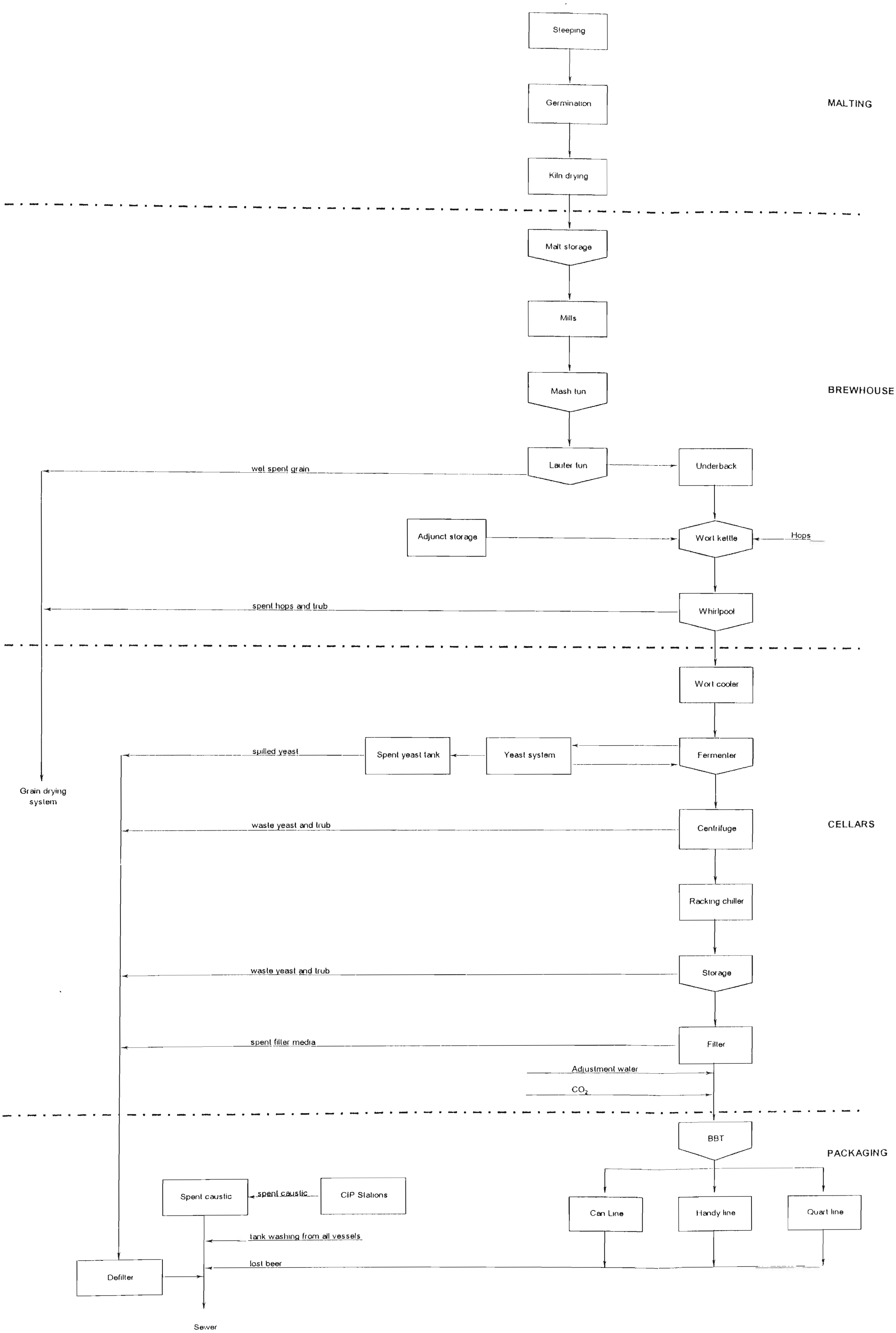


Figure 2.3 The flow diagram for Soputh African Breweries Rosslyn plant to be used in the analysis

At the start of the malting process the endosperm contents are in a stable high molecular weight form. These substances must be degraded to products of smaller molecules before they can be transported with water. This degradation is performed by enzymes which are formed during germination. During germination a new barley plant is produced from the kernel resulting in the formation of rootlets and a small shoot, which grows under the husk. (The husk consists of two overlapping leaf-like layers which were a part of the flower in which the seed was formed. It also forms the outer layer of the kernel and acts as a relatively waterproof and insect-proof protective barrier.)

As the barley kernels germinate, they produce enzymes which start to degrade the starch (in the kernel) into smaller carbohydrates, including some sugars (Wainwright, 1998). The next stage of malting is kiln drying. Here the germinated kernels, termed malt or malted barley, are dried to stop the modification of the enzymes and to produce a kilned malt which is dry enough to store for months. This kilned malt is responsible for much of the flavour, colour and foam of beer (Wainwright, 1998). South African Breweries purchases modified barley kernels, or malt, from external contracting companies, for example, Caledon Maltsers. At SAB's Rosslyn plant the malted barley is housed in storage silos from where it is transferred to the mills in the brewhouse. (As the malting process takes place outside of the SAB's brewing activities, its water use will not be considered in this thesis. However, typically 5 m^3 of water is used to produce 1 ton of malted barley and according to Binnie and Partners (1986), 3,4 m^3 of this volume exits the process as effluent, mostly due to the steeping process.)

2.3.2 Brewhouse

The brewhouse area at the brewery consists of the mills, mash tun, lauter tun, underback, wort kettle, whirlpool and relevent storage vessels (for the addition of hops and syrup). The malted barley is milled to expose the endosperm, thereby optimising the extraction of soluble substances (for example, starch and proteins) from the malt. To prevent too much fragmentation of the husk, some breweries treat the malt with water before milling in a process known as steep conditioning. (The Rosslyn brewery does not perform steep conditioning.) During milling the husk must be kept intact while the endosperm is crushed into smaller pieces. The husk is kept intact to ensure that during the separation of the spent grains from the wort in the lauter tun, the filter bed (formed from the kernel husks) in the lauter tun does not become to tightly packed with fine particles. The milled malt, now termed grist, exits the milling chamber, is mixed with water at a specified liquor to grist ratio, and is transferred to the mashing vessel (mash tun). The mixture of grist and water is termed mash. The liquor to grist ratio is dependent on the process and ranges from about 1:1 to 5:1 (volume:weight).

The process of mashing refers to the conversion of barley malt or mash, in the presence of enzymes, to a fermentable extract suitable for yeast growth and beer production. According to

Wainwright (1998), the enzymes present in the mash convert starch to sugars and proteins to free alpha amino nitrogen (FAN). This enzyme activity is temperature and pH specific making it possible to control the conversion of starch and proteins (Wainwright, 1998). The product from the mash tun is transferred to the lauter tun.

In the lauter tun, prior to the transfer of the mash, water is added in a process called underletting. This water is added to cover the false bottom of the lauter tun to ensure the even distribution of mash in the vessel and therefore facilitates the separation process. The main aim of the lautering process is to separate the husk fraction (or spent grain) from the mash liquor while collecting as much extract (fermentable sugars) as possible. The spent grain, which is removed from the mash liquor, is released to storage bins and sold to farmers as animal feed (Wainwright, 1998). After the bulk of the mash liquor has been extracted in the lauter tun, water is sprayed over the bed to recover any remaining liquor. This process is called sparging.

The mash liquor recovered in the lauter tun is temporarily stored in a vessel called the underback, before being sent to the wort kettle. The underback is a buffering facility to optimise the brew cycle time. During the transfer from the underback to the wort kettle, syrup or caramel adjunct is added to the mash liquor. (Adjuncts are substances which provide fermentable sugars in addition to those from the malt.) In the wort kettle, this mixture (termed sweet wort) is boiled with hops or hops products. The product from the wort kettle is called wort. (Wort is the mixture resulting from the mashing process and contains partially degraded starch, sugars, enzymes, proteins and water.) The main reasons for wort boiling include (Wainwright, 1998):

- wort sterilisation,
- coagulation and consequent precipitation of proteins,
- the removal of the volatile components,
- extraction of the hop bitter compounds,
- evaporation of water to obtain the correct extract concentration (gravity),
- achieving the correct colour, and
- the addition of the liquid adjuncts.

The hops added during wort boiling contain extractable compounds which, according to Wainwright (1998):

- suppress the growth of micro-organisms,
- impart a characteristic flavour and hops aroma,
- stabilise the foam compounds, and
- assist in clarifying the wort via precipitation with the coagulated proteins.

Boiling of the wort normally takes between one and two hours during which time approximately 5 – 15 % of the volume of product entering the wort kettle is evaporated (Wainwright, 1998). After the wort has been boiled, it contains suspended particles derived from waste hops (and proteins) and spent hops material, called trub. The boiled wort is transferred to a vessel named the whirlpool for the separation of the trub from the wort. In the whirlpool the hot wort swirls around while the suspended solids sink towards the bottom of the vessel. The suspended solids are stored in a trub tank, mixed with the spent grain and sold to farmers as animal feed (Pollution Research Group, 1987).

2.3.3 Cellars

The first area of cellars is called wort cooling where the wort leaving the whirlpool is cooled from approximately 95°C to between 9 and 10°C. The cooling, which facilitates the removal and enhanced settling of the trub, is accomplished in plate heat exchangers (Wainwright, 1998). The incoming cooling water, produced in the chilled liquor plant, exits the wort coolers for use as high temperature process water throughout the brewery. The cooled wort is transferred to the fermentation vessels.

Prior to entering the fermentation vessels, aeration of the wort occurs and a batch of yeast is added (or pitched). Aeration is necessary for the yeast to synthesise unsaturated fatty acids and sterols (which are vital cell components for the internal membranes of the yeast cells) while the yeast is an essential requirement for the fermentation process (Hulse, 2000).

During fermentation organic material is broken down into simpler compounds through the action of micro-organisms (yeast). In the brewery context, fermentation is where yeast metabolises wort sugars and other nutrients in order to multiply and also produce alcohol and carbon dioxide as major products (Wainwright, 1998). The growth requirements for the yeast cells are (Hulse, 2000):

- carbon sources - for energy which is obtained from fermentable sugars,
- nitrogen sources - for growth and enzyme synthesis,
- oxygen - for the production of lipids for membrane synthesis,
- vitamins - acting as growth factors,
- inorganic ions - required for yeast metabolism,
- water and
- yeast foods.

Fermentation can continue for 2 to 16 days depending on the time required to develop the characteristics of the beer (flavour compounds and alcohol percentage unique to the beer). During the fermentation process, yeast, CO_2 (continuously) and trub (not removed in the whirlpool) are removed from the vessel. At the end of the fermentation process, the product is called green or immature beer. Most of the yeast is removed and the green beer proceeds to storage or maturation (Wainwright, 1998).

The transfer of green beer to storage vessels for maturation is referred to as racking. To minimise the uptake of oxygen, the vessel and pipes are filled with deaerated water or carbon dioxide prior to being filled with the beer (Jones, 2000). (Deaerated water is produced in the deaeration water plant where water is flashed at a temperature above its boiling point, cooled and carbonated.) At the Rosslyn plant, the racking process includes centrifugal separation, chilling and carbonation steps. The main aim of centrifugation is to remove the yeast from the fermented beer before transferring to the storage vessel. Centrifugation accelerates the separation and settling of particles. Chilling reduces the temperature of the green beer to between - 1,5 to - 2,0°C, which is the optimal storage temperature for the beer. (The storage tanks at the Rosslyn plant, unlike other breweries, do not contain jackets or coils for lowering the temperature of the beer but utilise racking chillers.) During the carbonation phase, CO_2 is introduced into the beer to achieve the correct concentration in the beer and ensure that the quality of the beer is attained.

In addition to the above, green beer flavours are removed during storage by enzymatic reduction of the yeast. Remaining suspended matter, which causes the haze in beer, is also removed. The subsequent solid material, which settles out of the storage tanks, is drained. The beer remains in the storage tanks for up to 30 days.

To ensure that all yeast and chill haze (protein residues) are removed from the beer before packaging, the beer undergoes a filtration step. During filtration, the smaller particles still residing in the beer is separated from the beer. At the Rosslyn plant, kieselguhr filter aids are added to the beer inside candle filters to form a suitable filter bed. The spent filter aids are washed out of the filter during backwashing and discharged to the drains.

Since the Rosslyn plant makes and ferments worts with a relatively high initial extract content, the beer is blended with deaerated carbonated water to the correct alcohol content. After the filtration phase, deaerated carbonated water is added to the beer at a ratio of 0,44 m^3 per cubic meter of high gravity beer. The practice of brewing beer with a high initial extract content has been adopted to optimise equipment utilisation. (Brewing in smaller vessels also reduces the volumes of water and energy required and subsequently less effluents are produced.)

2.3.4 Packaging

After the high gravity beer has been adjusted with deaerated carbonated water, the beer is stored in bright beer tanks (BBT) until a line is planned to package the beer into relevant containers for distribution and consumption. The lines package the beer into 750 ml returnable bottles (called "quarts"), 340 ml non-returnable bottles (called "handys"), 340 ml or 450 ml cans and kegs, and on occasions into plastic bottles for sporting events. (At the Rosslyn plant facilities are not available to package the beer into kegs.)

Each unit process on a packaging line utilises water for, *inter alia*, cleaning or heat transfer. Simplified flow diagrams of the packaging line for returnable bottles and non returnable containers (cans and handys), depicted in Figure 2.4 and Figure 2.5 respectively, show that very few differences exist between the two packaging lines.

2.3.4.1 Packaging activities on the returnable bottle line

At the Rosslyn plant there are three returnable bottle lines. As shown in Figure 2.4, a returnable bottle line includes storage in the bright beer tanks, unpacking of empty returnable bottles, removal of existing crowns on returned bottles, bottle and crate washing, filling, pasteurisation, labelling, and packing into crates and on pallets.

Depalletiser, decrater and crate washer

Bottles are returned in crates (cases) stacked on pallets and the pallets disassembled into individual crates by a machine called the depalletiser. Depalletisers have gripper arms to hold a complete layer of 8 to 10 crates which place them onto a slow moving, wide conveyor. The crates are then orientated into a single file and any crowns (bottle lids), still remaining on the returned bottles, are removed by the decrowner. Decraters are then used to lift the bottles out of the crates onto a transfer conveyor, leading to the bottle washer, while the crates are moved via a different conveyer to the crate washer. In the crate washer, consisting of several compartments, the crates move on a conveyor and through a tunnel, where they are treated with high pressure jets. Detergents are used in specific compartments of the crate washer to facilitate the cleaning process. Dirt from the crates is separated from the water or detergent by straining, to allow for liquid reuse (ICBD, 2000).

Bottle washer

Dirty bottles are conveyed to the bottle washer consisting, like the crate washer, of several compartments. Bottle washers hold dirty bottles inside pockets on a continuous carrier chain in which they remain until they are discharged, clean at the end of a cycle. The continuous carrier chain, carrying the bottles, bends in a set pattern to ensure that the bottles undergo a series of jet cycles, *inter alia*, inversion, draining, steeping and rinsing until they are clean (ICBD, 2000).

A typical sequence of events inside the washer is as follows:

- bottle loading,
- pre-soaking and rinsing,
- immersion and
- rinsing.

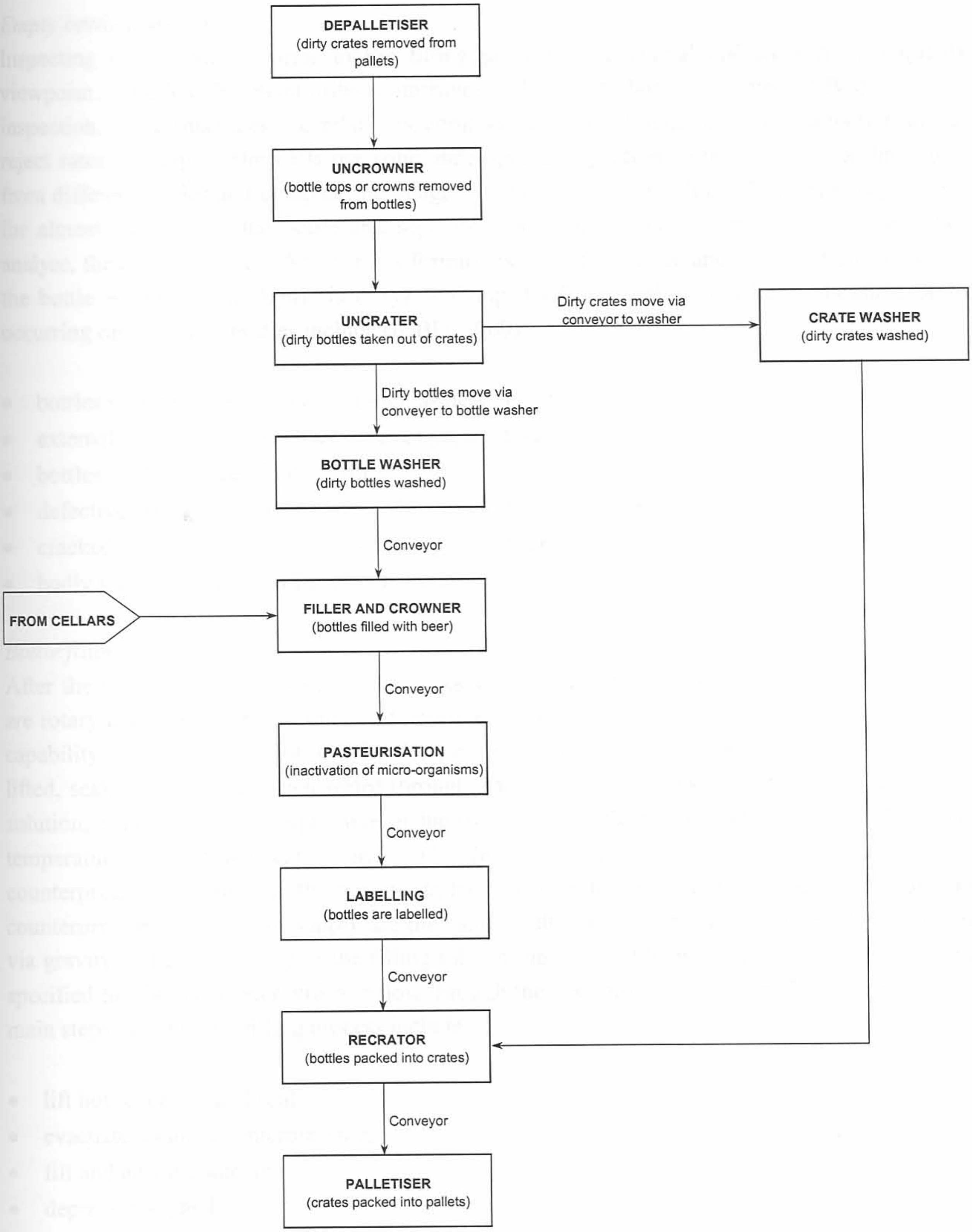


Figure 2.4 A simplified flow diagram of a returnable bottle packaging line.

Empty bottle inspector

Inspecting empty bottles, prior to the filling process, is a crucial operation from a quality viewpoint. The Rosslyn plant utilises machines called empty bottle inspectors (EBIs) for bottle inspection. The machines are relatively compact and do not require manual attention unless reject rates are large. The EBIs use solid state optical inspection systems to inspect the bottles from different angles and compare the images found with pre-set values. Inspection is provided for almost all parts of the bottle and separate sets of optical equipment illuminate, and then analyse, the different parts. Any non-conforming bottles are rejected and conveyed either back to the bottle washer (if the bottle is dirty) or dumped (if the bottle is cracked). Possible faults occurring on imperfect bottles include (ICBD, 2000):

- bottles with residual internal dirt such as dead insects,
- external contaminants such as traces of paper or adhesives,
- bottles containing residual caustic,
- defective bottle openings such as a chipped neck or damaged thread,
- cracked sidewalls or inclusions such as gas bubbles or ceramics, and/or
- badly scuffed bottles that have been used too often.

Bottle filler

After the bottle has been inspected for cracks and dirt, it is conveyed to the bottle filler. Fillers are rotary machines with a diameter of approximately 5 meters, up to 200 filling heads, and the capability of filling up to 100 000 bottles per hour. During filling, the bottles are individually lifted, sealed and the beer then added through a filling tube. To ensure that the CO_2 remains in solution, either a gas counterpressure or the isobarometric filling method is used and the filling temperature is held between 1 and 3°C. In the gas counterpressure method, a CO_2 gas counterpressure is applied to the system. In the isobarometric method, the bottle pressure and the counterpressure on the beer supply are the same so that the beer runs into the bottle effectively via gravity. The positioning of the filling tube in the beer bottle ensures that beer is added to a specified height, since beer will overflow through the vent pipe once this level is exceeded. The main steps in the bottle filling process include:

- lift bottle, centre and seal,
- evacuate air and counterpressure,
- fill and adjust contents,
- depressurise, and
- lower bottle and discharge.

Crowns should be applied to bottles as quickly as possible after filling to prevent air from entering the bottle and to prevent the loss of beer. As a result, the crowning machine (crowner) is integrated into the filler block to get full synchronisation in the two operations. Crowners are usually rotary machines with a number of heads or stations where the bottles are held for a few seconds while the crowns are placed on the bottle tops and then pressed into place (ICBD, 2000).

To prevent quality (taste and stability) problems, it is essential to remove any air present in the headspace of the beer bottle. This is achieved by a process called jetting where a fine stream of water enters the bottle to induce the beer in the filled bottle to rise as foam or fob and displace the air in the space above the beer (Maule, 1983).

Another aspect affecting the quality of the final product is the bottle fill heights. Bottle fill heights are either checked with a gamma source or by infrared methods. Incorrectly filled bottles are diverted back to the bottle washer where the beer is decanted to the drains, subsequently resulting in product loss and increased effluents (Dodd, 1987).

Pasteuriser

Once the beer has been carefully filled into clean bottles and sealed, it is pasteurised. Although the beer may be biologically clean at the time of filling, minor infection with bacteria, brewery yeast, or wild yeast (yeast strain not used by the brewery) would cause a rapid breakdown of the product. There are two types of pasteurisation, flash pasteurisation and tunnel pasteurisation. Flash pasteurisation involves using a plate heat exchanger to rapidly heat the beer up to a temperature of approximately 70°C, holding it at this temperature for some seconds, then chilling it down again. Tunnel pasteurisation, as used at the Rosslyn plant, involves slowly heating the bottle to the correct temperature, holding it at peak temperature (62°C) for a specified time interval and then slowly cooling the bottle down once again so that the bottle leaves the pasteuriser at approximately 30°C. The process normally takes one hour from the time a bottle enters the pasteuriser to the time it exits. This long time span is required since:

- the rate at which heat is conducted through the bottle wall and then through the beer is long,
- using a rapid temperature rise would cause thermal stresses which could result in the bottle bursting and therefore product losses, and finally
- as the highly carbonated beer bottle is heated, there is a steep rise in pressure which again poses a risk of bursting.

Bottles have a wide range of failure pressures but generally are manufactured to withstand pressures up to 6 bar. To prevent bottle breakage and still achieve the desired pasteurisation units over the unit process, a low temperature/long time profile is utilised. One pasteurisation unit (PU) is the unit obtained by holding beer at 60°C for 1 minute and is a measure of the time necessary to ensure the death of microorganisms within a bottle or can. Generally, a beer bottle is effectively pasteurised if 10 pasteurisation units are achieved.

In the pasteuriser, bottles slowly move through and are heated by spraying warm water (from spray sets) onto them. These spray sets are in zones across the length of the machine and are at set temperatures. The first zone, for example, will be at a temperature of 20 to 22°C, to warm the bottles up to between 9 and 10°C (the filled bottle generally enters the pasteuriser at a temperature between 5 and 7°C). The water falling past the bottles and through the conveyor carrying the bottles is collected within a trough underneath the pasteuriser. This water is used for reuse within another zone where cooling of the bottles is required. Water at progressively higher temperatures is sprayed onto the containers to bring them up to 60°C.

The most critical section in the pasteuriser is called the superheat zone which is the last heating zone before the zone where the temperature is held at 60°C. The temperature in the superheat zone must be very accurately controlled at between 61 and 65°C, to ensure that the containers are heated to the correct temperature. The temperature used is machine specific and therefore specified on commissioning to give the required pasteurisation units. Stoppages in the pasteuriser could result in bottles, within the superheat zone, to be overheated resulting in overpasteurisation and burst bottles.

Water in the cooling zones receive heat from the warm bottles exiting the pasteuriser and is pumped to the zones at the front of the pasteuriser where it is used to warm up the cold incoming bottles. The heated water will subsequently lose heat as a result and is then returned to the zones at the end of the pasteuriser to cool down more bottles. At the Rosslyn plant, the final zone of the pasteurisers used on the bottle lines is supplied with water from the cooling towers for efficient cooling of the bottles exiting the pasteuriser. This water is recycled back to the cooling towers.

Each zone in the pasteuriser has facilities for heating up and cooling down its reservoir to cater for start-up and shut-down conditions, as well as occasional stoppages. If the pasteuriser is in equilibrium, then only the superheat zone needs significant steam input, while the other zones require only small additions of water. The energy consumption in a tunnel pasteuriser is high and 50% recovery is the best that can be achieved, since the bottles enter the pasteuriser at between 5 and 7°C and leave at between 25 and 30°C. If a pasteuriser does get out of balance, for example when being emptied for cleaning purposes, then water consumption will rise due to the heat imbalance and overflow of the troughs since the cold water added must reach the correct temperature (ICBD, 2000).

Labeller

After pasteurisation, the bottles are conveyed to the rotary labellers for the application of labels on the bottles. The application of labels is done in stages in order to obtain the high speeds and consistency of glue application needed for a consistent quality appearance. The stages can be listed as follows;

- glue picked up by glue pallet,

- label picked up and glue applied,
- label transferred to the gripper,
- label transferred to the bottle, and
- label brushing.

Recrator and palletiser
Once the bottles are labelled they are packed back into crates. The method of loading returnable bottles is simply the reverse of the decrater machine where an array of clamping nozzles descends onto a batch of marshalled bottles and lifts them into the crates. This is performed by a machine called the recrater. Palletising of bottle packs involves arranging the crates in a pattern and then moving them onto a pallet. This is performed by a machine called the palletiser.

2.3.4.2 Packaging activities on the nonreturnable container line.

The packaging process for non-returnable bottles and cans (containers) has a few differences to that of the returnable bottle packaging lines and is shown in Figure 2.5. The differences between the two types of lines include, *inter alia*,

- the nonreturnable container line does not have bottle washers (bottles are new), but instead the containers are rinsed with a machine called the rinser,
- the nonreturnable container lines does not use uncraters or decrowners,
- cans are closed (seamed) by a machine called the seamer,
- filled containers are sorted in packs of six and shrinkwrapped in plastic by means of a machine called the shrinkwrapper, and
- these packs are then loaded onto trays by means of the traypacker.

Depalletiser
Most nonreturnable containers are on strapped pallets with thin layer-boards between each layer of cans. The pallet is located on a lift and raised to the height of the infeed conveyor, which is a broad slat or belt conveyor with the same width as the pallet. When the containers are level with the conveyor, the top cover board is removed and the first layer of containers are moved onto the conveyor by the depalletiser pusher arm. On the infeed conveyor, the containers are inspected for damage or contaminants, often by having an angled mirror on the side of the conveyor to assist in viewing (ICBD, 2000).

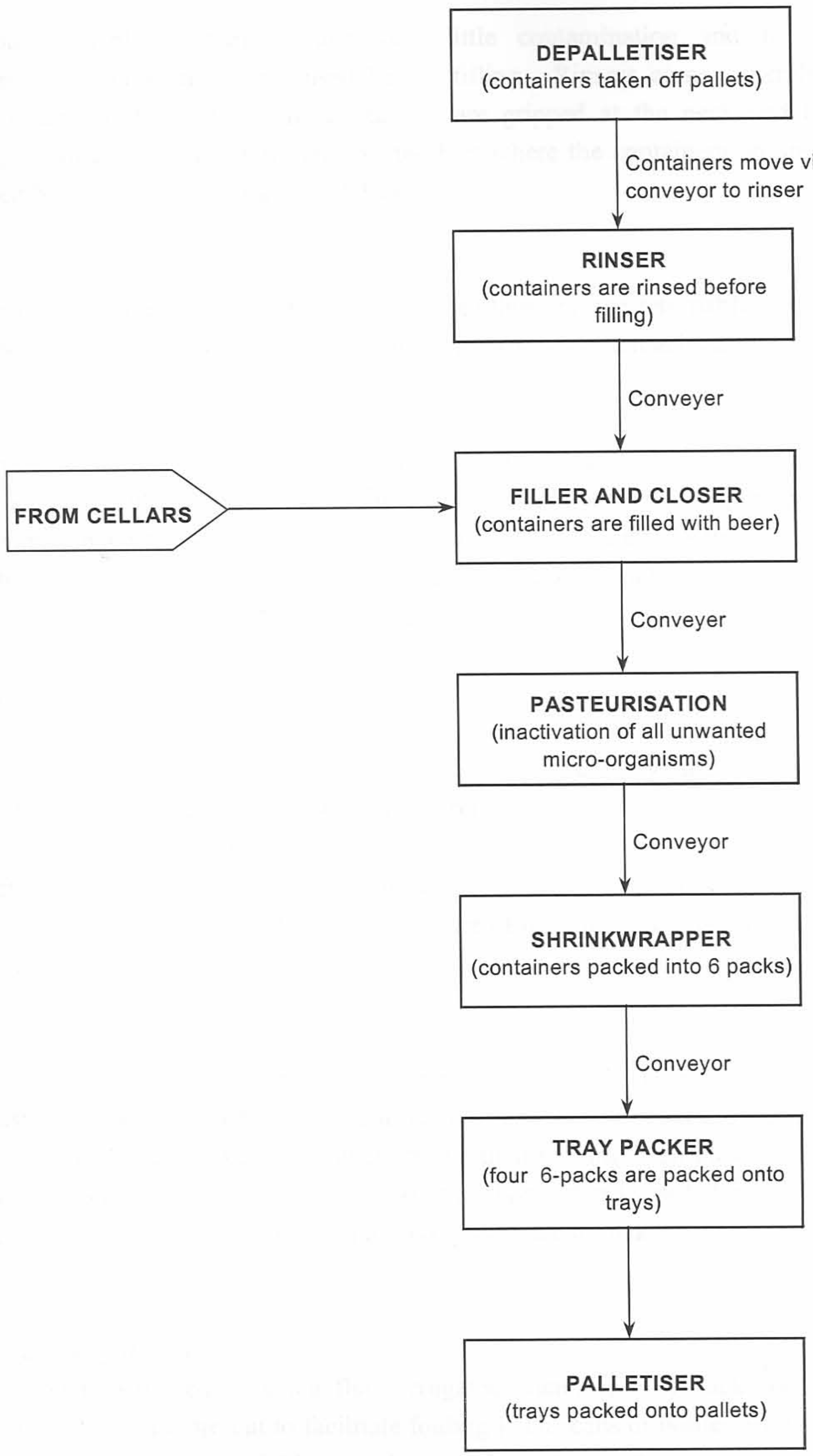


Figure 2.5 A simplified flow diagram of a nonreturnable bottle or can packaging line.

Rinsers

New non-returnable containers have very little contamination and to ensure complete decontamination, containers are rinsed before filling. Rinsers come generally in two forms, either a rotary machine where the containers are gripped at the neck and then inverted for spraying, or linear machines with an inverted belt where the containers are inverted and rinsed and placed back on a conveyor again (ICBD, 2000).

Filler

After rinsing, the containers are filled, similarly to those on the returnable bottle packaging line, and the nonreturnable bottles crowned and the cans seamed by a machine called the seamer.

Seamer

The seaming operation starts back at the filler discharge because the two operations of filling and seaming are fully linked. Fillers are coupled to the seamer and must be perfectly timed to ensure smooth can transfer to avoid, *inter alia,* spillage and fallen cans. After filling, the beer in the cans is topped with foam, containing air which may cause spoilage, which is removed by CO_2 injected into the cans, prior to the seaming operation (ICBD, 2000).

Pasteuriser

Once the bottles and cans are filled and closed, they are pasteurised to kill any microorganisms which may have entered the container. The pasteurisation activity on a can line is very similar to that on a bottle line, except that the water used to rinse the cans in the final zone passes straight to the drains and is not recycled to cooling towers. The reason for the Rosslyn plant not recycling water between the pasteuriser and the cooling towers is that cans come into direct contact with a person's mouth when drinking the beer and water of drinking water quality is thus used to rinse the containers.

Shrinkwrapper

Completed cans and bottles from a packaging line are usually grouped together, six in a pack, with plastic shrinkwrapped by a machine called the shrinkwrapper. Shrinkwrapping involves folding a sheet of plastic over the containers and then moving it on the conveyor through a heat tunnel at between 180 and 200°C, whereupon the plastic shrinks and clings to the containers in a firm pack. The most common way of packaging cans are to make them up into a case of 24 cans (ICBD, 2000).

Traypacker and palletiser

Tray packing is achieved by using flat corrugated blanks from a stack and folding them into shape. (The blanks are pre-cut to facilitate folding.) The cans or bottles are first pushed onto the centre of the board, the sides folded in, glued on the ends and the tray ends folded up to stick to the sidewall overlap piece. Hot melt glue is usually used for this application. If the tray is shrinkwrapped as well, then the two functions are combined in one machine. Tray packing is performed by a machine called the traypacker.

Successive layers of trays alternate in pattern to ensure that there is enough friction to hold them together. Between 8 and 11 layers are typically put into a full pallet, depending on can size. This is all done by a machine called the palletiser (ICBD, 2000).

2.4 WATER MANAGEMENT

As discussed thus far, there are many unit operations involved in a brewery, all consuming water. Specific water use within the brewing process (excluding those associated with malting) will be discussed in the proceeding chapters. A simplified water balance of the water utilised within the Rosslyn plant is shown in Figure 2.6. From the diagram it can be seen that water used inside the brewery either becomes part of the beer, part of the effluent or is evaporated (during wort boiling). The water ratio is described as the ratio of total volume water entering the brewery (A) to the total volume of beer leaving the brewery (B). Ideally, the volume of the effluent (stream C) should be minimised which would reduce the costs of effluent treatment and the costs paid for water, since stream A would also decrease. A major source of effluent in a brewing environment emanates from cleaning operations, since beer is a consumable product and it is important to maintain a clean brewing environment.

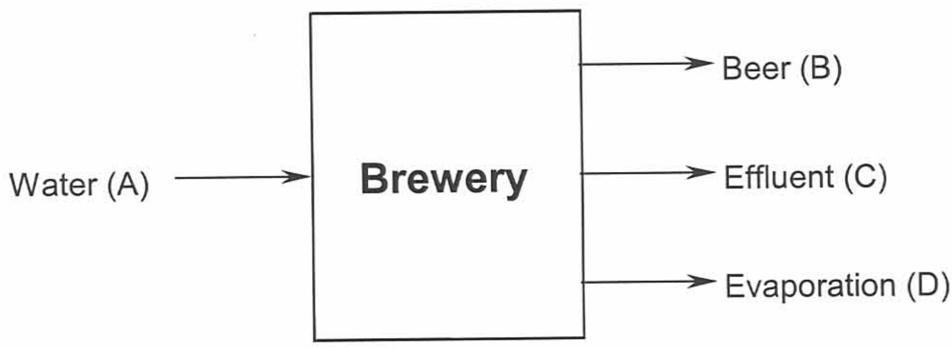


Figure 2.6 Simplified water balance of the Rosslyn plant.

All vessels and pipelines frequently undergo cleaning in place (CIP) which becomes part of the effluent stream. The purpose of the CIP is to ensure that the product is safe for human consumption by keeping the equipment clean. It also ensures that the product is of the correct quality required. Therefore the CIP must be effective, repeatable and deodorising. At the Rosslyn plant they use a solution recovery system which reduces the water and chemical consumption. The vessel to be cleaned is often first rinsed with recovered water from an earlier cycle. A typical CIP regime (dependent on the vessel to be cleaned) employed at the Rosslyn plant includes the following:

- pre-rinse with water from the recovered water tank,
- detergent rinse (typically caustic soda) – to penetrate and remove the organic deposits on the vessel walls,
- water rinse (to remove the detergent in the vessel),
- acid rinse (typically phosphoric/nitric acid) – to neutralise alkaline residues and penetrate and remove the inorganic deposits on the walls,
- water rinse – to remove the acid in the tank,
- sterilent rinse – to sanitise, and finally
- water rinse – to remove residual sterilent in the tank.

Optimisation of these cleaning cycles in the brewery may thus reduce effluent volumes. According to Binnie and Partners (1986), between 65 and 70% of incoming water forms part of the effluent leaving a brewery. In the past, effluent charges associated with this water, were not very high. However, with the drive towards the conservation of the environment, companies are charged higher levies for the discharge and treatment of effluent. It is therefore very costly for a brewery to get rid of waste water and also very expensive to purchase fresh water. The cost of disposal of effluents to, for example, local authority sewage works, depends upon the volume, the concentration of suspended and total solids, and the ability of the effluents to take up oxygen. Therefore every attempt should be made to reduce the volumes of water used and minimise the amount of suspended material in the waste water.

Chapter 3

BREWHOUSE

3.1 INTRODUCTION AND BACKGROUND

The Rosslyn brewery has two brewhouses for wort production, namely brewhouse 1 and 2, which operates simultaneously and will be referred to as the "brewhouse" for the remainder of this section. To provide the necessary conditions for fermentation, the initially insoluble components in the malt must be converted into soluble products, and in particular soluble fermentable sugars must be produced. The formation and dissolving of these compounds is the purpose of wort production. The brewhouse is capable of producing approximately 2 500 hl of wort per brew (of which 1 000 hl is produced by brewhouse 1, 1 500 hl is produced by brewhouse 2 and a brew refers to the combined outputs from brewhouses 1 and 2). The operations in a brewhouse are batch related and one brew takes approximately three hours (brewlength).

The brewhouse operations include milling, mashing, lautering, buffering in the underback, preheating, wort boiling and separation in the whirlpool (see Figure 3.1). The brewery brews high gravity wort (wort with a high concentration of fermentable sugars) for better equipment utilisation within the brewery. This also reduces the size of vessels needed during wort production and therefore also reduces the volumes of water required to clean the vessels per volume of wort brewed. Each brand of beer has its own unique recipe (based, *inter alia*, on the amount of process water added during production) to ensure a brand's unique characteristics. However, these differences in water consumption of the various brands are negligible and this investigation (thesis) is based on the most commonly brewed brand at the brewery, "Castle".

3.1.1 Malting

Malting does not occur on the brewery site itself and is therefore not considered in this investigation.

3.1.2 Mills

The brewhouse is equipped with five mills in parallel to service brewhouses 1 and 2. (However, only three mills are used to supply the brewhouse at a given time.) The malt is milled accurately to the correct particle size distribution. Water is used in the conditioning chamber of the mills to assist in the milling process and the mills also undergo a CIP clean two times per week.

3.1.3 Mash tuns

Before the process of mashing occurs, water is added to obtain the correct liquor to grist ratio. During the transfer of the mash from the mash tuns to the lauter tuns, water is used to transfer any mash, remaining within the pipelines, to the lauter tuns. After the mash has been transferred, the mash tuns are rinsed with water to remove any mash still remaining in the vessels. This water is discharged to the drains. The mash tuns undergo a CIP clean two times per week.

3.1.4 Lauter tuns

Before the transfer of mash from the mash tuns, underletting occurs where water is added to the lauter tuns to ensure an even distribution of mash within the vessels. After the majority of the wort has been separated from the husk fraction, water is sprayed over the bed in the lauter tuns to wash out any remaining extract. The separation of the mash liquor from the husk fraction is optimised to give the correct volume to the underbacks with minimal extract loss. The volume of mash liquor transferred to the underbacks is determined from analyses of the process. Any remaining mash liquor and water in the lauter tuns are discharged to the drains.

The spent grain, with a moisture content of approximately 80%, is transferred to the spent grain storage bins by air blowers and sold to farmers as animal feed. Once the spent grain is removed from the lauter tuns, the vessels are rinsed with water to remove any waste still residing within the vessels. The lauter tuns undergo a CIP clean two times per week.

3.1.5 Underbacks

The underbacks are utilised as buffer tanks prior to wort boiling. On completion of the transfer of the mash liquor to the wort kettles, a measured volume of water is utilised to transfer any mash liquor, remaining in the pipelines, to the wort kettles. The underbacks undergo a CIP clean two times per week.

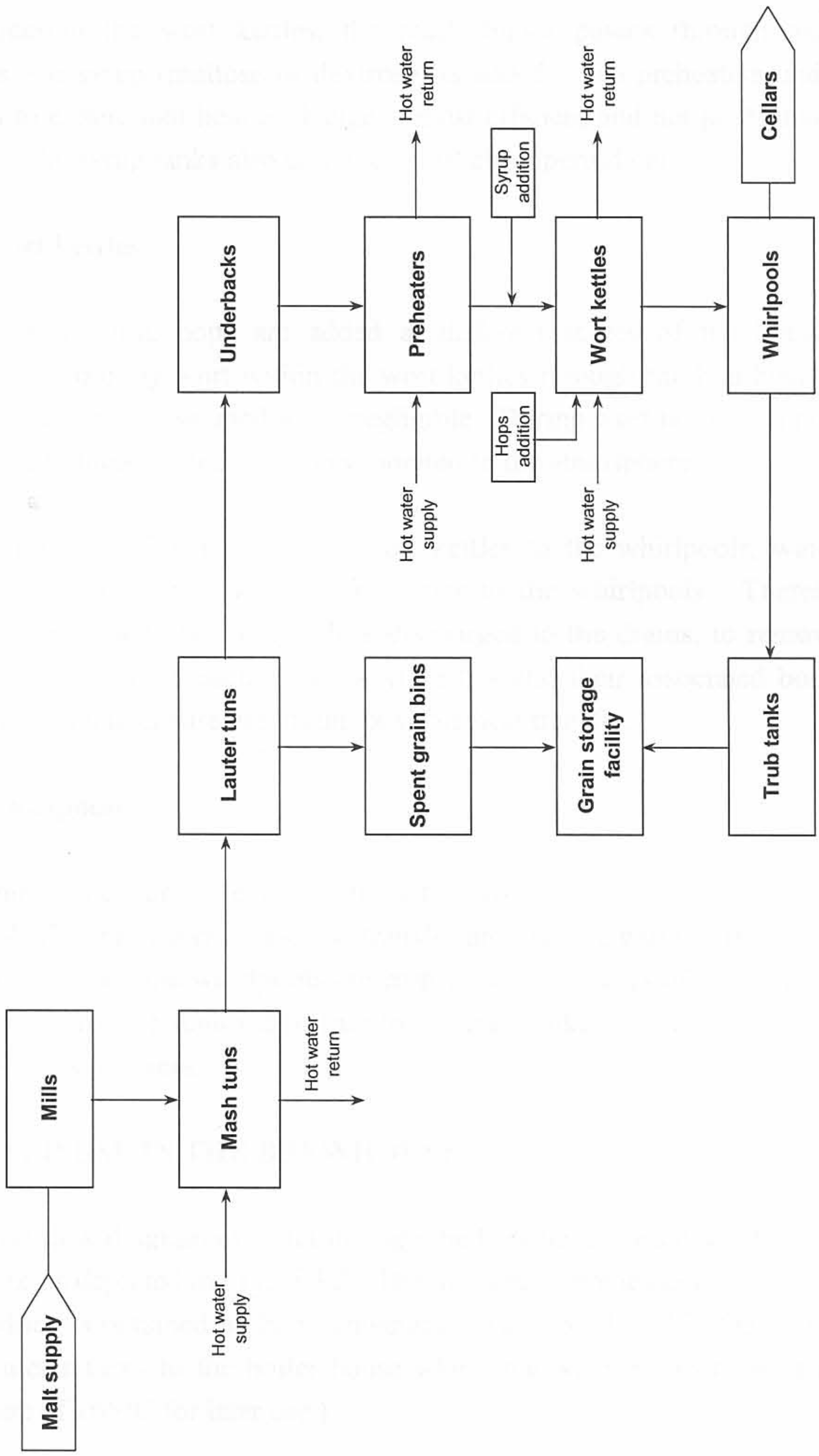


Figure 3.1 Flow diagram of the brewhouse at the South African Breweries Rosslyn plant.

3.1.6 Preheaters and syrup addition

Before entering the wort kettles, the mash liquor passes through plate and frame preheaters and syrup (maltose or dextrose) is added. The preheaters undergo a regular CIP clean to ensure that heat exchange is most efficient and not prohibited by the build-up of dirt. The syrup tanks also undergo a CIP clean periodically.

3.1.7 Wort kettles

During wort boiling, hops are added at different stages of the boiling process by circulating the boiling wort within the wort kettles through the hop bins. The moisture content in the hops is assumed to be negligible. During wort boiling, approximately 6 to 8% (volume/volume) of the wort is evaporated to the atmosphere.

After the transfer of wort from the wort kettles to the whirlpools, water is added to transfer any wort remaining in the pipelines to the whirlpools. Thereafter, the wort kettles are rinsed with water, which is discharged to the drains, to remove any wort or trub remaining in the vessels. The wort kettles and their associated boilers undergo a regular CIP clean to ensure maximum possible heat transfer.

3.1.8 Whirlpools

In the whirlpools, trub is separated from the wort and the wort transferred to the wort coolers. Additional water is used to transfer any wort remaining in the pipelines to the wort coolers. Once the whirlpools are empty, large volumes of water is utilised to rinse the whirlpools for the removal of trub to the trub tanks. The whirlpools undergo a CIP clean two times per week.

3.2 WATER USE IN THE BREWHOUSE

The general flow diagram of water through the brewhouse, assuming the brewhouse to be a black box, is depicted in Figure 3.2. The mash tuns, preheaters and wort kettles require heating which is obtained by high temperature water produced in the boiler house. (The cooled water returns to the boiler house where the water is maintained at the required temperature of 165°C for later use.)

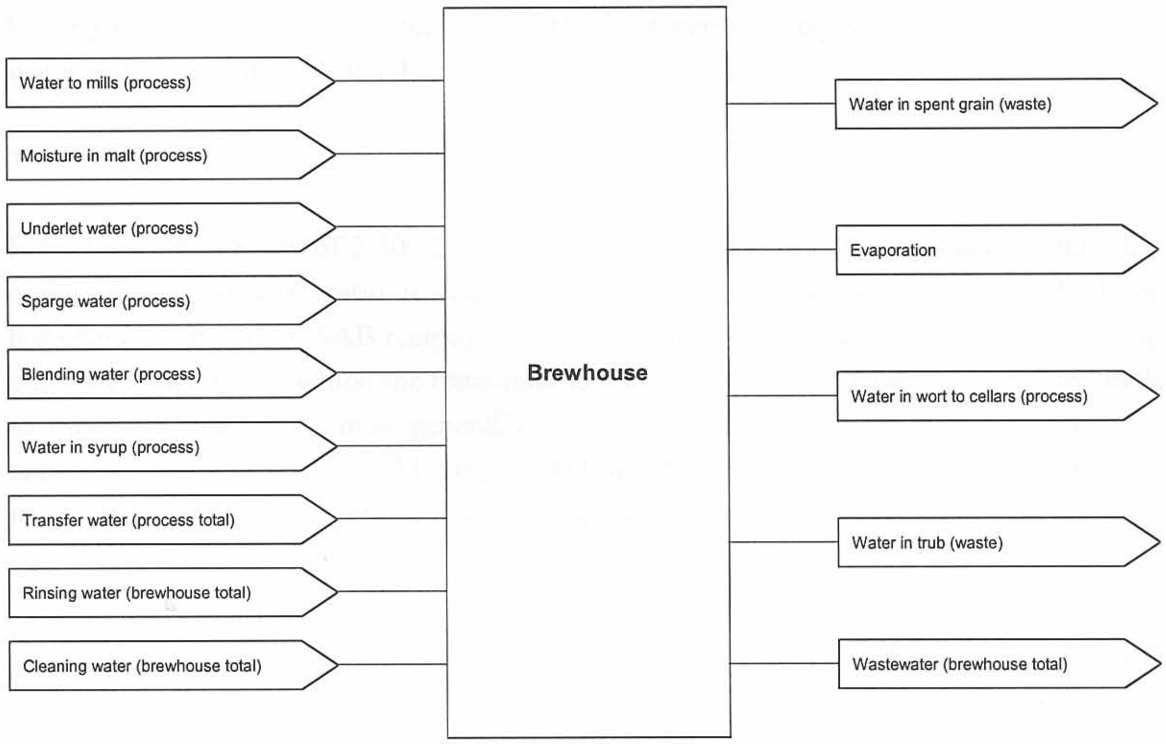


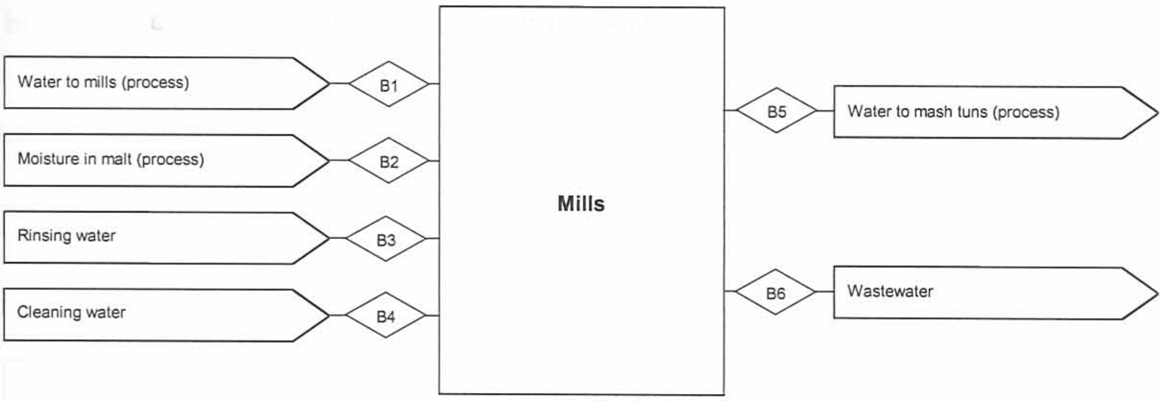
Figure 3.2 Simplified water balance over the entire brewhouse.

To determine the quantity of water, measured in hl, used per hl of beer brewed, a mass balance over each unit process was completed. This analysis will use one brew from each brewhouse, with a total brewing capacity of 2 500 hl, as a basis to determine water use per week. Water in the brewhouse is either used as brewing (process) water, rinse water or cleaning water. The average volume of beer brewed per day, based on production figures and assuming a five day week and 24 hours production per day, is 15 950 hl (Naik, 2000). Therefore, approximately 6,4 brews per day (or 32 brews per week) are brewed in the brewhouse.

Except for transfer and underlet water, all process water (for the production of wort) is measured and controlled. Water used for transferring, underletting, rinsing and cleaning, over each of the unit processes within the brewhouse, is unmeasured and is supplied by one pump station consisting of five pumps operating in parallel. The pumps supply hot water into a common header which services the brewhouse, cellars and packaging sections. It is assumed that the pumps operate at 80% efficiency (total capacity 4 650 hl/h) and that equal amounts of water are transferred to the brewhouse, cellars and packaging sections. From the above, the flowrate of water used for rinsing, transfer and cleaning, under normal operating conditions, is calculated as 1 240 hl/h. Water used for heating of the mash tuns, preheaters and the wort kettles is considered with the general water used in the brewery in Chapter 6.

3.2.1 Mills

For a brewing capacity of 2 500 hl, approximately 1 330 hl of water is added to attain the correct liquor to grist ratio (calculated as 530 hl for brewhouse 1 and 800 hl for brewhouse 2, based on SAB recipe). A portion of this water is added in the conditioning chamber of the mills, whilst the remainder is added during the transfer of the milled malt to the mash tuns. The malt generally has a moisture content, on a volume basis, of approximately 4 % (Caledon Maltings, 2000) and therefore approximately 16 hl of water is added per brew (based on 406 hl of malt added).



Stream	Volume [hl]	Frequency	Ave volume/week [hl/week]	Source ⊕
B1	1 330	per brew *	42 560	S1
B2	16	per brew	512	S2
B3	83	per brew	2 656	S3
B4	1 860	per week +	1 860	S3
B5	1 346	per brew	43 072	B1 + B2
B6	-	-	4 516	B3 + B4

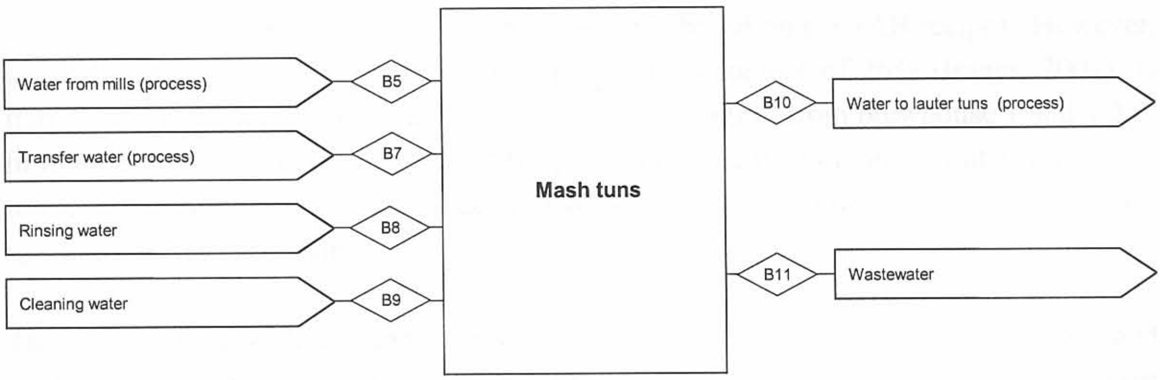
⊕ Sources, other than streams, are presented at the end of each chapter. * per brew means for both brewhouses. + per week indicates for both brewhouses per week.

Figure 3.3 Water balance over the mills.

Water is used to rinse the mills, after the transfer of the milled malt to the mash tuns (therefore after each brew), at a rate of 1 240 hl/hour for 40 seconds (van der Merwe, 2000). Therefore, 83 hl of water (calculated as 41,5 hl of water for the three mills in brewhouse 1 and 41,5 hl of water for the three mills in brewhouse 2) is utilised for rinsing and discharged to the drains. Twice per week, three mills will undergo a CIP clean with an estimated total water use of 1 860 hl of water per week, which is discharged to the drains (van der Merwe, 2000).

3.2.2 Mash tuns

The water balance over the mash tuns is shown in Figure 3.4. After the transfer of the mashed malt to the lauter tuns, water is transferred through the pipelines, at a rate of 1 240 hl/h for 58 seconds per mash tun (van der Merwe, 2000), to transfer any remaining mash out of the pipelines to the lauter tuns. Therefore, the volume of water required to transfer the mash out of the pipelines per brew (for two mash tuns, one each from brewhouses 1 and 2), which forms part of the product, is 40 hl.



Stream	Volume [hl]	Frequency	Ave volume/week [hl/week]	Source ⊕
B5	1 346	per brew	43 072	-
B7	40	per brew	1 280	S3
B8	17	per brew	544	S3
B9	1 200	per week	1 200	S3
B10	1 386	per brew	44 352	B5 + B7
B11	-	-	1 744	B8 + B9

⊕ Sources, other than streams, are presented at the end of each chapter.

Figure 3.4 Water balance over the mash tuns.

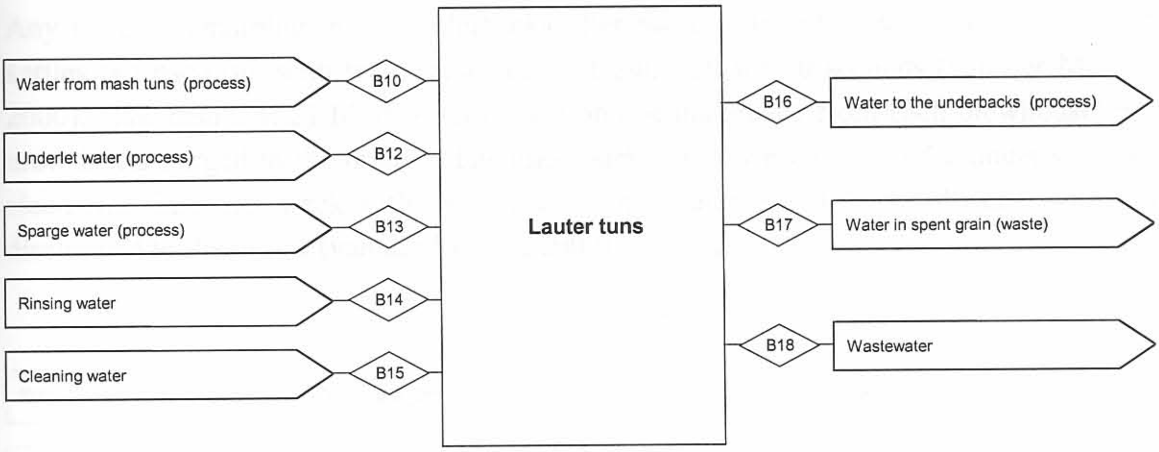
Once the transfer of mash is complete, water is utilised to rinse the vessels at a rate of 1 240 hl/h for 25 seconds per mash tun (van der Merwe, 2000), resulting in 17 hl of water used for rinsing per brew. The two mash tuns in the brewhouse (one each from brewhouses 1 and 2) undergo a CIP clean two times per week with an estimated total water use of 1 200 hl/week, which is discharged to the drains (van der Merwe, 2000).

3.2.3 Lauter tuns

The water balance over the lauter tuns is shown in Figure 3.5. Underlet water is added before the transfer of mash liquor from the mash tuns at a rate of 1 240 hl/h for 60 seconds (van der Merwe, 2000). Therefore approximately 41 hl of water is added per brew (for two lauter tuns, one each from brewhouses 1 and 2) for underletting, which also becomes part of the product.

After the majority of the mash liquor has been removed from the lauter tuns, sparge water is sprayed over the beds at a specific flowrate unique to the brand of beer being brewed. Approximately 1 305 hl of sparge water is added to the lauter tuns per brew (calculated as 570 hl for brewhouse 1 and 735 hl for brewhouse 2, based on the SAB recipe). However, in total only 2 250 hl of mash liquor, with a solids content of 26% (Isaacs, 2001), is transferred to the underbacks per brew (calculated as 900 hl from brewhouse 1 and 1 350 hl for brewhouse 2, based on the SAB recipe). Therefore the volume of water transferred to the underback with the mash liquor is 1 665 hl. The remaining mash liquor and water are discharged to the drains.

The spent grain with an approximate moisture content of 80% (Isaacs, 2000) and containing an estimated 75 hl of water per brew, is transferred to the spent grain storage bins. After all the spent grain is removed from the lauter tuns, each lauter tun is rinsed at a rate of 1 240 hl/h for 200 seconds to remove any remaining residue from the vessel (van der Merwe, 2000). Therefore 138 hl of water is utilised during each brew to rinse the lauter tuns and this water is discharged to the drains. The lauter tuns undergo a CIP clean two times per week with an estimated total water use of 2 000 hl/week (for two lauter tuns, one each from brewhouses 1 and 2), which is discharged to the drains (van der Merwe, 2000).



Stream	Volume [hl]	Frequency	Ave volume/week [hl/week]	Source ⊕
B10	1 386	per brew	44 352	-
B12	41	per brew	1 312	S3
B13	1 305	per brew	41 760	S1
B14	138	per brew	4 416	S3
B15	2 000	per week	2 000	S3
B16	1 665	per brew	53 280	S1
B17	75	per brew	2 400	S5
B18	-	-	38 160	B10 + B12 + B13 +B14 +B15 – B16 - B17

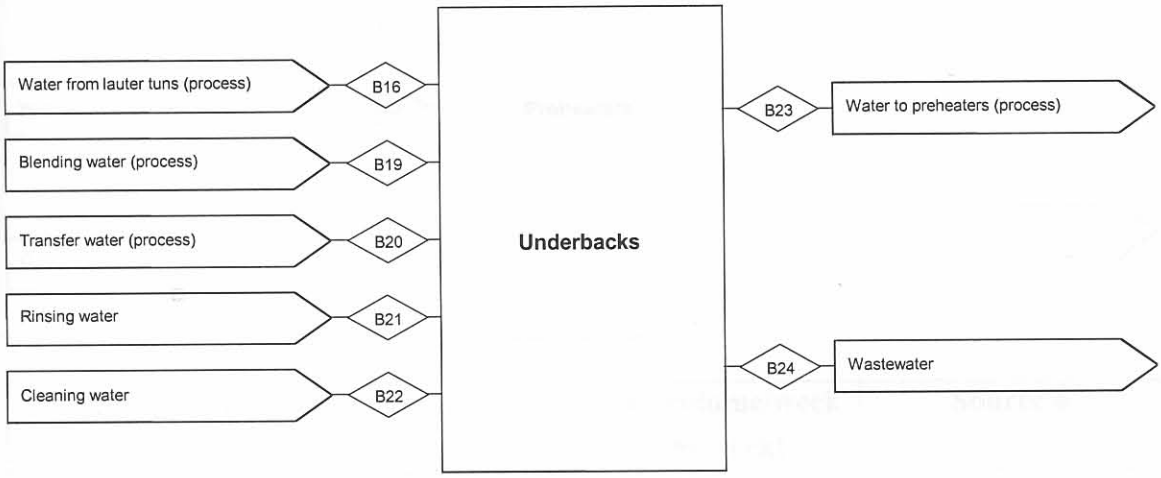
⊕ Sources, other than streams, are presented at the end of each chapter.

Figure 3.5 Water balance over the lauter tuns.

3.2.4 Underbacks

The water balance over the underbacks is shown in Figure 3.6. Water is blended with the process liquor in the underbacks (prior to the transfer to the wort kettles) and amounts to a total volume added of 475 hl (calculated as 200 hl for brewhouse 1 and 275 hl for brewhouse 2, based on SAB recipe). On completion of the transfer of liquor to the wort kettles, 75 hl of water is added to transfer any liquor remaining in the lines to the wort kettles (calculated as 40 hl for brewhouse 1 and 35 hl for brewhouse 2) and this volume forms part of the product (Isaacs, 2001).

Any residue remaining in the underbacks after the transfer of mash liquor to the wort kettles is rinsed out with water at a rate of 1 240 hl/h for 30 seconds (van der Merwe, 2000). The resultant 21 hl of water (based on one underback from each brewhouse) per brew is discharged to the drains. The underbacks in brewhouses 1 and 2 undergo a CIP clean two times per week with an estimated total water use of 1 600 hl/week, which is discharged to the drains (van der Merwe, 2000).



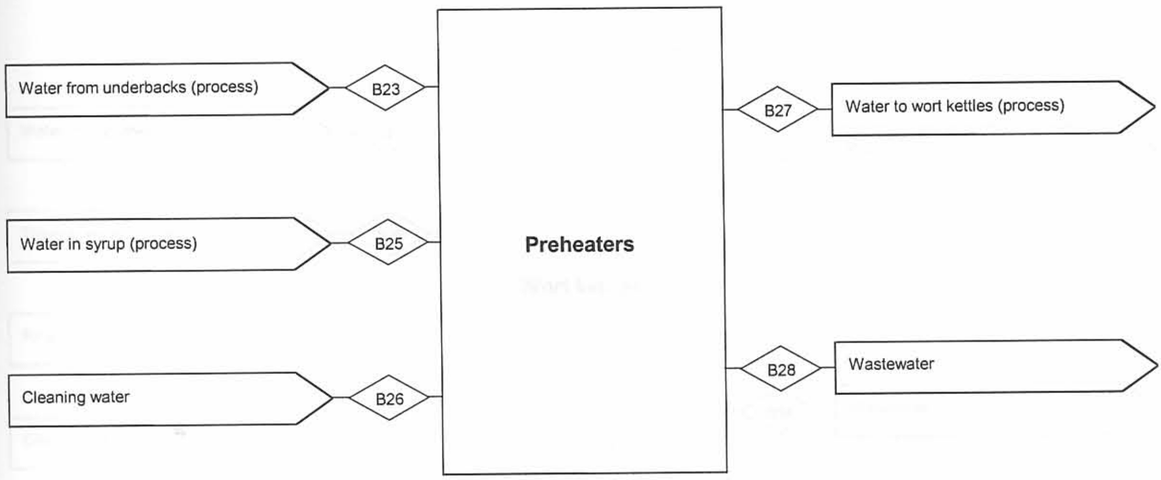
Stream	Volume [hl]	Frequency	Ave volume/week [hl/week]	Source ⊕
B16	1 665	per brew	53 280	-
B19	475	per brew	15 200	S1
B20	75	per brew	2 400	S5
B21	21	per brew	672	S3
B22	1 600	per week	1 600	S3
B23	2 215	per brew	70 880	B16 + B19 + B20
B24	-	-	2 272	B21 + B22

⊕ Sources, other than streams, are presented at the end of each chapter.

Figure 3.6 Water balance over the underbacks.

3.2.5 Preheaters and syrup addition

The water balance over the preheaters, including syrup addition, is shown in Figure 3.7. 15 225 kg of syrup, with an estimated water content of 22 % and a density of 1 380 kg.m^{-3}, is added to the process liquor during the transfer of wort to the wort kettles (Isaacs, 2001). Therefore, 110 hl of syrup, with a water content of 24 hl, is added per brew. The preheaters undergo CIP cleaning after every brew with an estimated total water use of 100 hl per brewing cycle, which is discharged to the drains (van der Merwe, 2000).



Stream	Volume [hl]	Frequency	Ave volume/week [hl/week]	Source ⊕
B23	2 215	per brew	70 880	-
B25	24	per brew	768	S5
B26	100	per brew	3 200	S3
B27	2 239	per brew	71 648	B23 + B25
B28	100	per week	3 200	B26

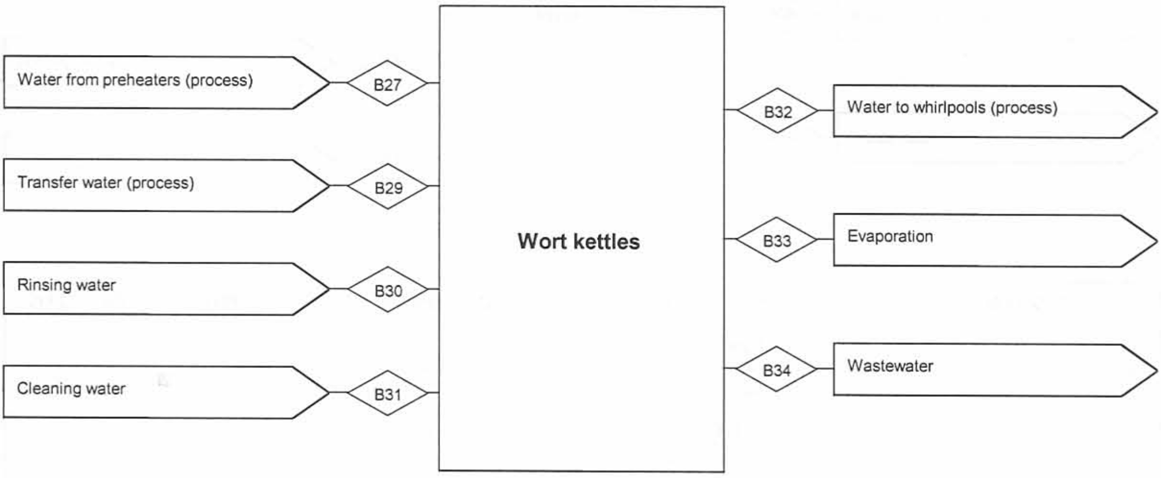
⊕ Sources, other than streams, are presented at the end of each chapter.

Figure 3.7 Water balance over the preheaters (including syrup addition).

3.2.6 Wort kettles

The water balance over the wort kettles is shown in Figure 3.8. During the boiling of the mash liquor in the wort kettles, approximately 7 % of the liquor, on a volume basis, is lost to atmosphere (Isaacs, 2000). Therefore, approximately 157 hl of water is evaporated to the atmosphere per brew.

On completion of the transfer of wort to the whirlpools, water is used at a rate of 1 240 hl/h for 65 seconds to transfer any remaining wort in the pipeline to the whirlpools (van der Merwe, 2000). The resultant 45 hl of water (based on two wort kettles) forms part of the product. The wort kettles are also rinsed at a rate of 1 240 hl/h for 30 seconds after each brew to remove any remaining residue (van der Merwe, 2000). Therefore 21 hl of water is used for rinsing the vessels and is discharged to the drains. The wort kettles, including their internal boilers, undergo a CIP clean twice every 5 brews with an estimated total water use of 140 hl per cleaning (van der Merwe, 2000). Thus an additional 1 792 hl of water is discharged to the drains per week.



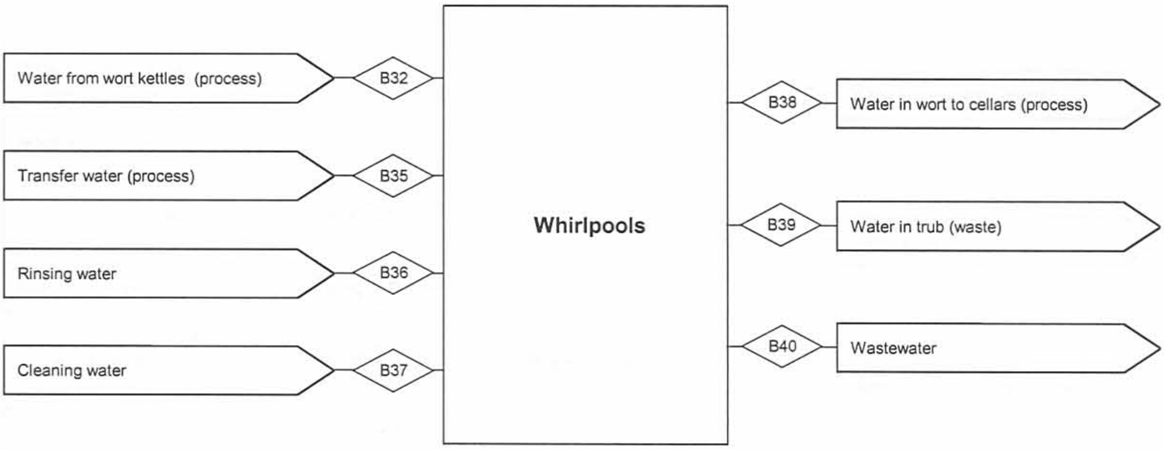
Stream	Volume [hl]	Frequency	Ave volume/week [hl/week]	Source ⊕
B27	2 239	per brew	71 648	-
B29	45	per brew	1 440	S3
B30	21	per brew	672	S3
B31	1 792	per week	1 792	S3
B32	2 127	per brew	68 064	B27 + B29 – B33
B33	157	per brew	5 024	S5
B34	-	-	2 464	B30 + B31

⊕ Sources, other than streams, are presented at the end of each chapter.

Figure 3.8 Water balance over the wort kettles.

3.2.7 Whirlpools

The water balance over the whirlpools is shown in Figure 3.9. After the transfer of the wort to the wort coolers, water is added at a rate of 1 240 hl/h for 150 seconds to transfer any remaining wort in the line to the wort coolers (van der Merwe, 2000). Therefore, an additional 103 hl of water (for the two whirlpools) is added during every brew and forms part of the product.



Stream	Volume [hl]	Frequency	Ave volume/week [hl/week]	Source ⊕
B32	2 127	per brew	68 064	-
B35	103	per brew	3 296	S3
B36	276	per brew	8 832	S3
B37	1 200	per week	1 200	S3
B38	2 205	per brew	70 560	B32 + B35 – B39
B39	25	per brew	800	S5
B40	-	-	10 032	B36 + B37

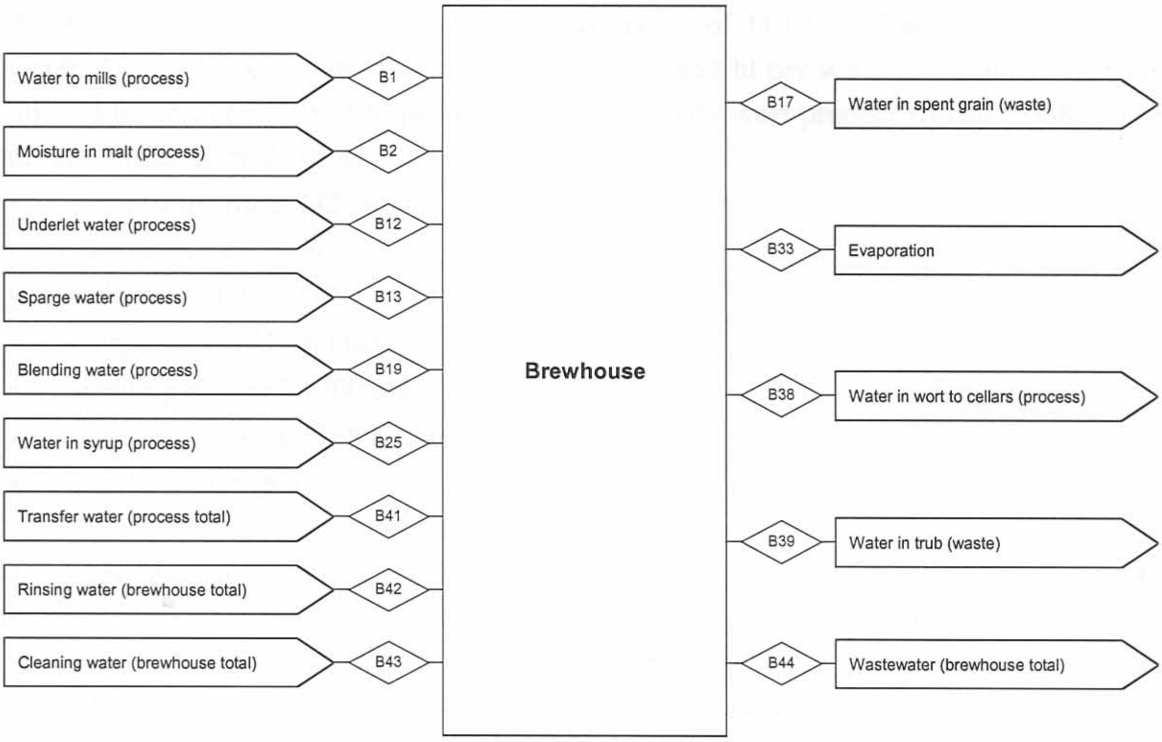
⊕ Sources, other than streams, are presented at the end of each chapter.

Figure 3.9 Water balance over the whirlpools.

The whirlpools are rinsed to remove any trub still residing in the vessels at a rate of 1 240 hl/h for 400 seconds (van der Merwe, 2000). The resultant 276 hl of water used per brew for the two whirlpools is discharged to the drains. The trub remaining in the whirlpools (containing approximately 25 hl of water per brew) is sent to the trub tanks from where it is mixed with the spent grain and sold to farmers as animal feed (Isaacs, 2000). The whirlpool in each brewhouse is cleaned twice a week with an estimated total water use of 1 200 hl/week, which is discharged to the drains (van der Merwe, 2000).

3.3 OVERALL WATER BALANCE OVER THE BREWHOUSE

The overall water balance over the brewhouse is shown in Figure 3.10.



Stream	Volume per week (hl/week)	Source
B1	42 560	Section 3.2.1
B2	512	Section 3.2.1
B12	1 312	Section 3.2.3
B13	41 760	Section 3.2.3
B17	2 400	Section 3.2.3
B19	15 200	Section 3.2.4
B25	768	Section 3.2.5
B33	5 024	Section 3.2.6
B38	70 560	Section 3.2.7
B39	800	Section 3.2.7
B41	8 416	B7 + B20 + B29 + B35
B42	17 792	B3 + B8 + B14 + B21 + B30 + B36
B43	12 852	B4 + B9 + B15 + B22 + B26 + B31 + B37
B44	62 388	B6 + B11 + B18 + B24 + B28 + B34 + B40

Figure 3.10 Overall water balance for the brewhouse at the Rosslyn plant.

A total of 141 172 hl of water per week (consisting of 110 528 hl per week of process water, 17 792 hl per week of rinsing water and 12 852 hl per week of cleaning water) is utilised to produce 70 560 hl per week of high gravity wort product (Stream B38). The process water is made up of:

- water to the mills (42 560 hl),
- moisture in the malt (512 hl),
- underlet water (1 312 hl),
- sparge water (41 760 hl),
- blending water (15 200 hl),
- water in the syrup (768 hl), and
- transfer water (8 416 hl).

The water used for cleaning (12 852 hl) and rinsing (17 792 hl) of vessels, in total 30 644 hl per week, forms part of the wastewater discharged to the drains. During the boiling of the mash liquor in the wort kettles, 5 024 hl of process water is lost to the atmosphere through evaporation. A further 3 200 hl of process water is lost through the disposal of spent grain and trub byproducts, which are sold to farmers as animal feed.

Finally, the Rosslyn plant brews high gravity wort for better equipment utilisation and water conservation. However, the ratio of hl of water used to hl of beer produced (a ratio commonly utilised by the brewing industry to depict water usage, Wainwright, 1998) is based on normal gravity wort. Since blending with water, to obtain normal gravity wort, only occurs in the cellars section, the high gravity wort volume is adjusted with the blending ratio (as utilised in the cellars section) to evaluate the water consumption within the brewhouse. A blending ratio of 0,44 parts of water to 1 part of wort is used at the Rosslyn brewery (SAB, 2000) and therefore 101 606 hl of normal gravity wort equivalent is prepared by the brewhouse. The ratio of water used to beer produced can therefore be calculated as:

$$(\text{Ratio of water used : beer produced})_{\text{brewhouse}} = \frac{141172}{101606} = 1{,}39 \ \ (\text{v/v})$$

The water balance in this chapter does not include water for washdown and other losses. These streams will be considered in Chapter 6.

3.4 SOURCES

The sources used within this chapter for calculating the different water balances over the brewhouse are presented below.

Source	Reference
S1	SAB (2000a) "Beer Division Brewing Manual", Johannesburg.
S2	Caledon Maltings (2000) "Malt Analysis", supplied on delivery of malt at the Rosslyn brewery, George.
S3	Van der Merwe, A.I. (2000) "Water Report for Brewhouse and Cellars" report to SAB Rosslyn plant, Pretoria.
S4	SAB (2000b) "Process Best Operating Practices", SAB Rosslyn plant, Pretoria.
S5	Isaacs, N. (2001) "Operation in the SAB Rosslyn Brewhouse", Personal Communication, Rosslyn Brewery, Pretoria.

CHAPTER 4

CELLARS

4.1 INTRODUCTION AND BACKGROUND

The wort prepared in the brewhouse is transferred to the cellars where fermentation, maturation and filtration of the beer are among the important unit processes. The characteristics unique to a beer are established in this section, thus requiring good process control and cleanliness. A flow diagram of the cellars section is shown in Figure 4.1. The cellars operations include wort cooling, yeast pitching, fermentation, racking, maturation and temporary storage, prior to packaging.

4.1.1 Wort cooling

The wort prepared by the brewhouse is cooled in the wort coolers, the first process in the cellars section, to the correct temperature to facilitate the functioning of the yeast cells. After all the wort is cooled to the correct temperature and transferred to the fermentation vessels, water is used to transfer any wort remaining in the transfer lines to the fermentation vessels. Before the transfer of wort from the wort coolers to the fermentation vessels, water is also transferred through the lines to prevent the uptake of dissolved oxygen into the beer which may cause, *inter alia,* taste problems. The water used before and after the transfer of the wort to the fermentation vessels is discharged to the drains. The wort coolers also undergo a regular CIP clean to prevent the build-up of dirt which may decrease the effectiveness of the heat transfer.

4.1.2 Yeast pitching

During the transfer of wort to the fermentation vessels, yeast and oxygen is added, or pitched, to the wort. The yeast is carefully prepared in a separate yeast area and used in a fermentation vessel for up to six generations, whereafter it is scrapped (also termed wasted). During scrapping the wasted yeast is transferred to the scrap yeast plant where the dried yeast is packed into bags and sold to farmers as a nutritional supplement for their animals. When the yeast is withdrawn from a fermentation vessel and reused, the yeast is said to be cropped. New yeast enters the propagation vessels and is allowed to multiply before being pitched into the fermentation vessels. To prevent microbiological contamination, the yeast vessels and pipelines are cleaned on a regular basis.

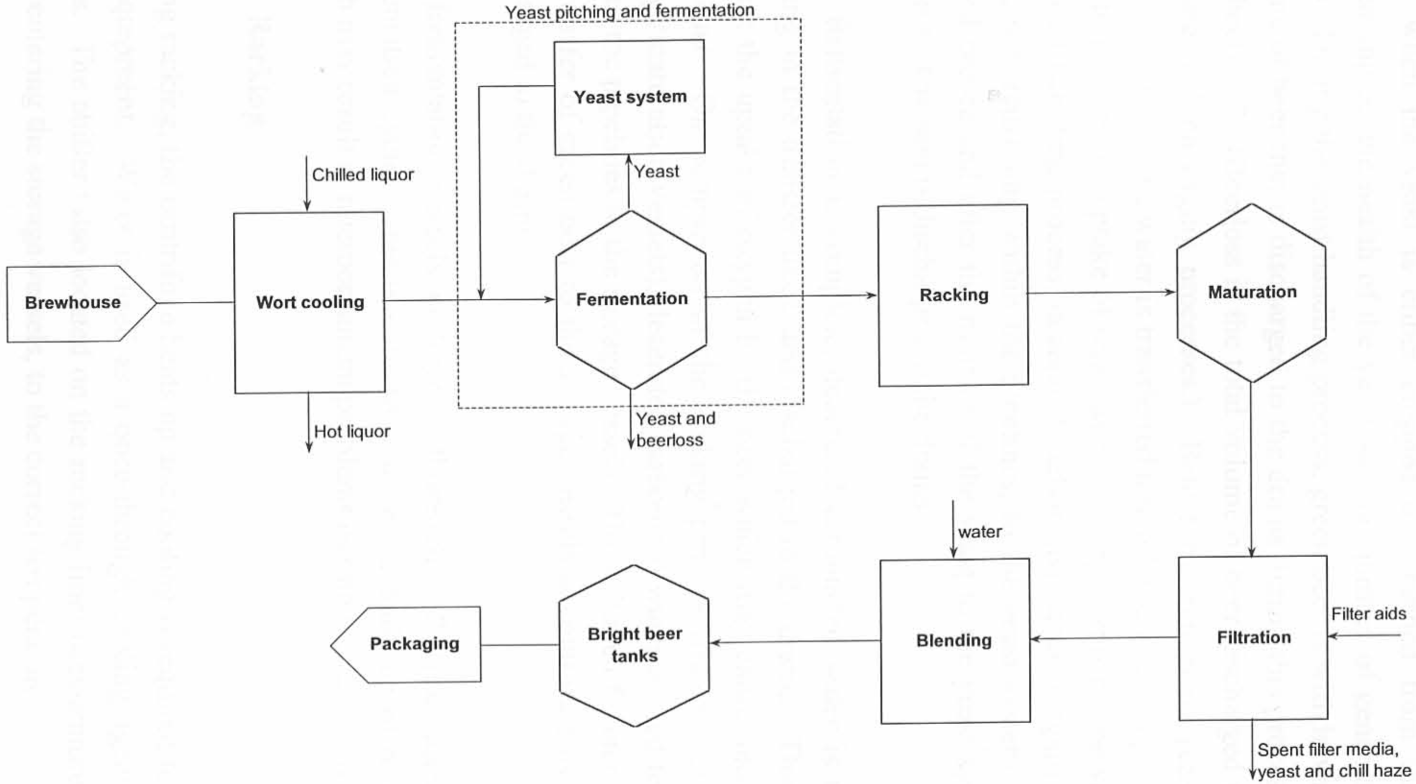


Figure 4.1 Flow diagram of the cellars section at the Rosslyn plant.

4.1.3 Fermentation

During the fermentation process, yeast is withdrawn from the fermentation vessels as explained in Section 4.1.2. At the Rosslyn plant, this happens only once per fermentation cycle when the yeast is either cropped or scrapped from the fermentation vessels (depending on the health of the yeast and the number of generations the yeast has been used). During the yeast handling process, green beer is withdrawn with the yeast and the volume of beer that is discharged to the drains during this process, is considered part of the "beerloss". (Beerloss is the total volume of beer discharged to the drains during the brewing and packaging processes.) Before the return of yeast to the yeast system, deaerated carbonated water is transferred through the yeast cropping or scrapping transfer lines to prevent the uptake of unwanted microorganisms by the yeast. On completion of the yeast handling process, deaerated carbonated water is again utilised to transfer any yeast, still remaining within the pipelines, to the yeast system. The volume of water utilised before and after the transfer of the yeast to the yeast system is controlled by a timing system and is discharged to the drains.

Once fermentation is complete, deaerated carbonated water is used to remove the air residing in the transfer lines, and discharged to the drains. This practice is adopted to prevent the uptake of oxygen by the beer which may cause, *inter alia,* flavour stability problems. On completion of the racking process (transfer of the green beer to the storage/maturation vessels), deaerated carbonated water is used to transfer any remaining beer in the pipelines to the storage vessels. The volume of water utilised before and after the transfer of green beer to the storage vessels is controlled by a timing system and is discharged to the drains.

The fermentation vessels undergo a thorough CIP clean after the completion of a fermentation cycle. This is done to remove the build-up of residue within the vessels which may result in microorganism problems during the next fermentation.

4.1.4 Racking

During racking, the centrifuge heats up and cooling is required to prevent any damage to the equipment. Water is used as a once-through cooling agent and discharged to the drains. The chiller (also located on the racking line) uses ammonia in cooling the green beer, entering the storage vessels, to the correct temperature.

4.1.5 Maturation (storage vessels)

During storage, maturation of the beer takes place and the beer remains in the storage vessels for several days, until the beer flavours have been developed. On completion of maturation, and before the beer is transferred to the filtration system, deaerated carbonated water is used to remove air residing in the transfer lines. This prevents the uptake of oxygen by the beer which may cause beer spoilage. After all the beer is transferred to the filtration system, deaerated carbonated water is again utilised to transfer any beer still remaining in the line to the filtration system. The volume of water utilised before and after the transfer of beer to the filtration system is controlled by a timing system and is discharged to the drains.

As with the fermentation vessels, the storage vessels undergo a thorough CIP clean after each maturation cycle to prevent the build-up of residue within the vessels, which could result in microorganism problems.

4.1.6 Filtration

During filtration, impurities in the beer are removed in the filtration system by using filter aids. (The filter aids, prepared in a separate plant, are added to the beer before filtration to form a suitable filter bed.) Before transfer of the beer from the storage vessels, the filtration system is filled with deaerated carbonated water to prevent the uptake of air by the beer. As the beer enters the filters, it displaces the water which is discharged to the drains. The filtered beer product is transferred to the filtration buffer tanks.

The filters, filtration buffer tanks, filter aid make-up tanks and filtration lines undergo a weekly CIP clean. The filters are also backwashed once the allowable pressure drop across a filter is exceeded. At the Rosslyn plant, backwashing occurs after each filter has treated approximately 5 000 hl of beer and this water is discharged to the drains. During backwashing, a small fraction of beer, which forms a part of the beerloss over the brewery, is discharged to the drains with the spent filter aids. Prior to backwashing, the filtration system is completely filled with deaerated carbonated water to transfer any beer still residing within the system to blending. This water is controlled by a timing system and discharged to the drains.

4.1.7 Blending and bright beer tank cleaning

Deaerated carbonated water is blended at a 44 % volume to volume ratio with filtered beer downstream of the filter buffer tanks. This blending, which represents the final product, is then transferred to the bright beer tanks (BBTs).

At the Rosslyn plant, the BBTs form part of the packaging section. However, the water utilised for their weekly CIP cleaning is supplied by the cellars section and will thus be addressed under this section.

4.2 WATER USE IN THE CELLARS

The general flow diagram of water utilised in the cellars section is shown in Figure 4.2. The cellars section consists of batch and continuous processes. The fermentation, maturation and temporary storage units are batch processes, while the racking and filtration units are continuous.

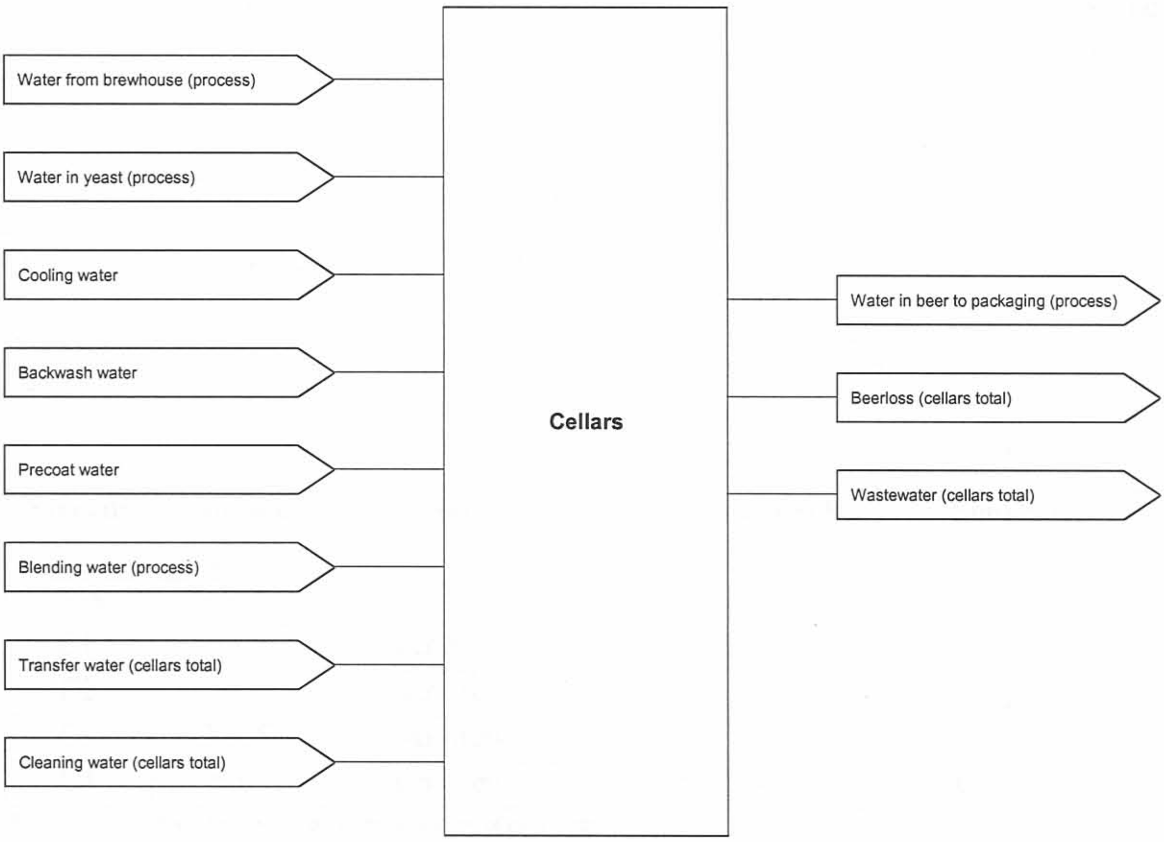


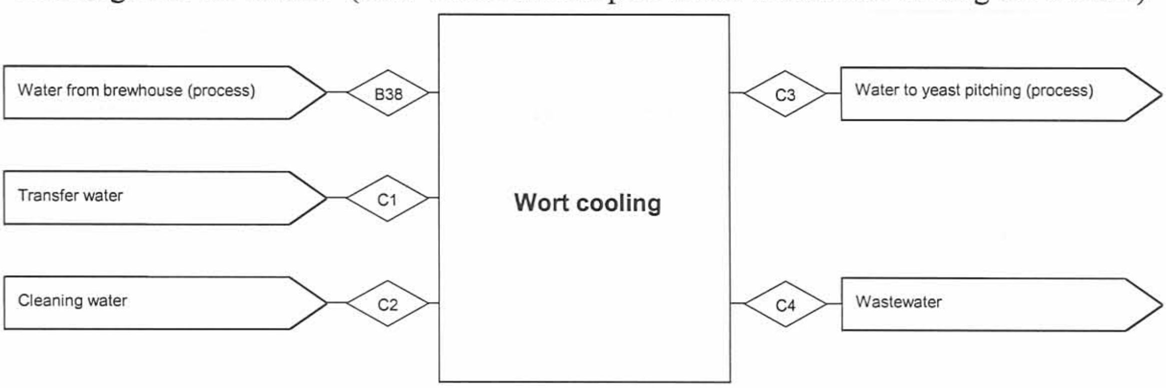
Figure 4.2 Simplified water balance over cellars.

Cooling of the various unit processes in the cellars section is mostly effected by ammonia, obtained from the utilities section. During wort cooling, however, chilled water is used. (The hot liquor produced from wort cooling is used in brewhouse operations, as discussed in Chapter 3.)

Water used for the cleaning of the vessels and the lines forms a large portion of the water used within the cellars section. A water balance was completed over the unit processes to define the volumes of water used by each process. A basis of 2 500 hl, equivalent to one brew (comprising of one brew from brewhouse 1 and one brew from brewhouse 2) produced within the brewhouse section, will also be used within the cellars section.

4.2.1 Wort cooling

The water balance for wort cooling is shown in Figure 4.3. Before the transfer of the wort to the fermentation vessels, 160 hl of water per brew is transferred through the transfer lines to prevent the uptake of microorganisms (Van der Merwe, 2000). On completion of a transfer, 80 hl of water per brew is used to transfer any wort remaining in the lines to the fermentation vessels (Van der Merwe, 2000). Therefore 240 hl of water is used before and after the transfer of the wort to the fermentation vessels per brew and discharged to the drains. (This water forms a part of the wastewater exiting the cellars.)



Stream	Volume [hl]	Frequency	Ave volume/week [hl/week]	Source ⊕
B38	2 205	per brew	70 560	-
C1	240	per brew	7 680	S3
C2	367	per brew	11 744	S4
C3	2 205	per brew	70 560	B38
C4	607	per brew	19 424	C1 + C2

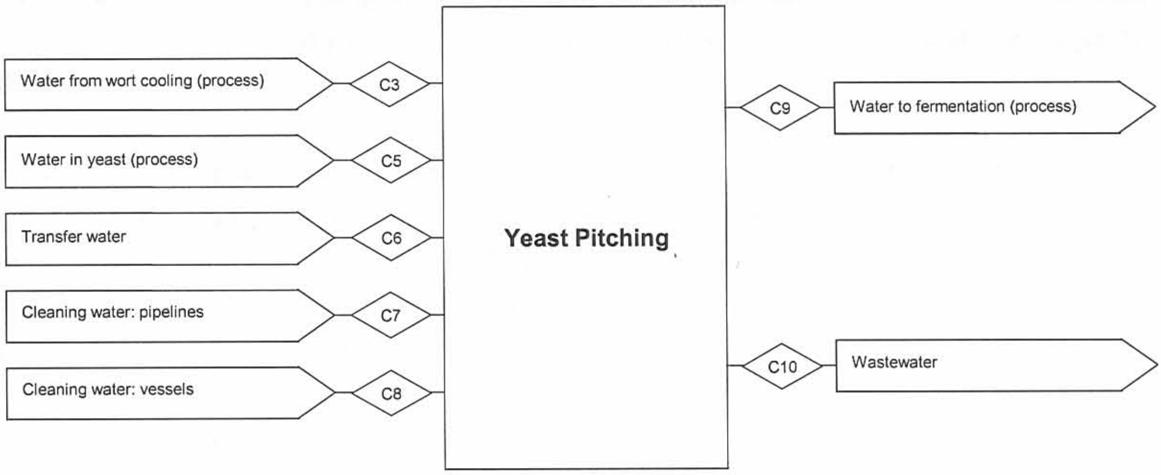
⊕ Sources, other than streams, are presented at the end of each chapter.

Figure 4.3 The water balance for wort cooling.

The wort coolers undergo a CIP clean after each brew at a rate of 1 100 hl/h for approximately 20 minutes. The resultant 367 hl of water used per brew for CIP cleaning is discharged to the drains.

4.2.2 Yeast pitching

The water balance for yeast pitching is shown in Figure 4.4. At the Rosslyn plant, the fermentation vessels have a volume of 3 000 hl and are used to accommodate one brew produced in the brewhouse section (comprising one brew from brewhouse 1 and one brew from brewhouse 2). The yeast required for fermentation is pitched through one pitching pipeline to the wort during its transfer to the fermentation vessels. Before and after the transfer of the yeast from the yeast pitching vessels (per brew), water is transferred through the transfer lines at a rate of 1 400 hl/h for a total time of 210 seconds and discharged to the drains (Van der Merwe, 2000). Therefore 82 hl of water is utilised before and after yeast pitching per brew and discharged to the drains.



Stream	Volume [hl]	Frequency	Ave volume/week [hl/week]	Source ⊕
C3	2 205	per brew	70 560	-
C5	15	per brew	480	S6
C6	82	per brew	2 624	S3
C7	1 555	per week	1 555	S4
C8	2 250	per week	2 250	S4
C9	2 220	per brew	71 040	C3 + C5
C10	-	-	6 429	C6 + C7 + C8

⊕ Sources, other than streams, are presented at the end of each chapter.

Figure 4.4 The water balance for yeast pitching.

Approximately one kg of a yeast solution (containing on average 50% water and 50% yeast) is pitched per hl of wort mixture (water and wort solids) from the brewhouse (Bradfield, 2001). Therefore, if the solution has a density of 1 000 kg/m^3 (Bradfield, 2001) and the wort mixture from the wort coolers has a solids content of 26% (Isaacs, 2001), 15 hl of water is added to each brew during yeast pitching.

There are four yeast pipelines for the transfer of yeast, two within the yeast plant and two for pitching to the fermentation vessels. The pipelines are cleaned once every two days at a rate of 250 hl/h for 20 minutes. Therefore 833 hl of water is used per week to clean the four yeast pipelines and discharged to the drains. There are also two yeast cropping lines which undergo a thorough CIP clean twice every three days, whilst the two yeast scrapping lines undergo a CIP clean, on average, once per week. These lines are cleaned at a flowrate of 250 hl/h for 20 minutes. Therefore 722 hl of water is used per week for CIP cleaning of the cropping and scrapping lines and discharged to the drains. In total, 1 555 hl of water is used for CIP cleaning of the yeast system pipelines and discharged to the drains.

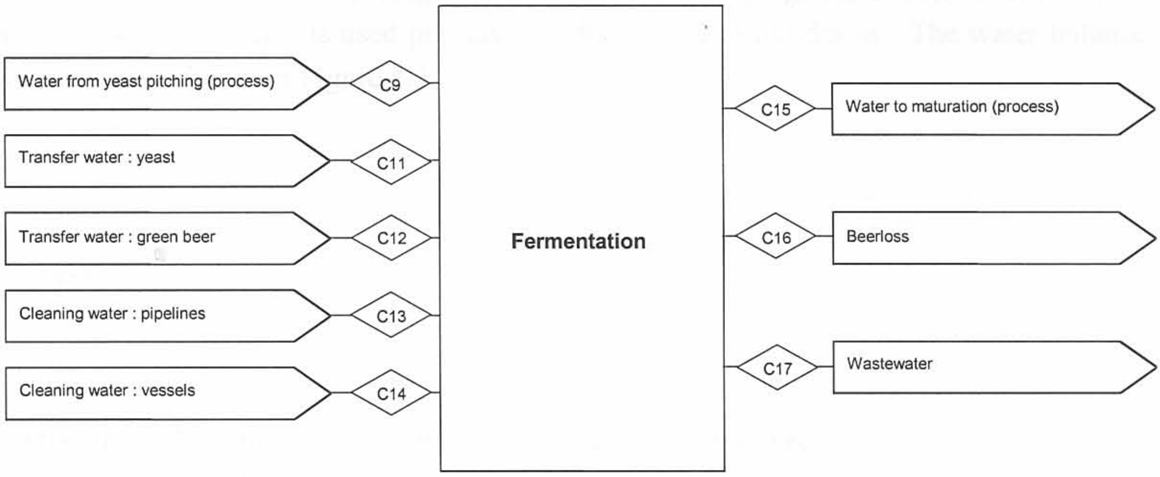
At the Rosslyn plant, the yeast plant consists of 18 yeast vessels for the propogation, scrapping, cropping and pitching of the yeast. Each vessel undergoes a CIP clean once every two days at a rate of 150 hl/h for 20 minutes to prevent microbiological contamination. The resultant 2 250 hl of water used for CIP cleaning of the yeast vessels per week is discharged to the drains.

4.2.3 Fermentation

The water balance for fermentation is shown in Figure 4.5. Yeast is cropped or scrapped from the fermentation vessels only once during a fermentation cycle, as explained in Section 4.1.3. A single cropping or scrapping line is used for this yeast transfer. Before and after the return of yeast to the yeast system, water is transferred through the cropping or scrapping lines at a rate of 200 hl/h for a total time of 475 seconds (Van der Merwe, 2000). The resultant 26 hl of water used per brew during the yeast transfer forms part of the wastewater exiting the cellars. The yeast cropping and scrapping pipelines undergo a CIP clean, as discussed in Section 4.2.2.

When yeast is withdrawn from the fermentation vessels, a small volume of beer is lost with the cropped (or scrapped) yeast, as discussed in Section 4.1.3. It is estimated that 3% of the beer contained within the fermentation vessels, on a volume basis, is lost with the yeast (Naik, 2001). Therefore, approximately 67 hl of process water exits the vessels with the yeast (for disposal from the yeast plant) and constitutes beerloss from the process.

Before and after the transfer of green beer to the storage vessels (maturation), deaerated carbonated water (at a rate of 600 hl/h and a total time of 360 seconds) is used to remove air residing in the transfer lines (Van der Merwe, 2000). The resultant 60 hl per brew is discharged to the drains.



Stream	Volume [hl]	Frequency	Ave volume/week [hl/week]	Source ⊕
C9	2 220	per brew	71 040	-
C11	26	per brew	832	S3
C12	60	per week	1 920	S3
C13	292	per day	1 460	S4
C14	187	per brew	5 984	S4
C15	2 153	per brew	68 896	C9 – C16
C16	67	per brew	2 144	S7
C17	-	-	10 196	C11 + C12 + C13 + C14

⊕ Sources, other than streams, are presented at the end of each chapter.

Figure 4.5 The water balance for fermentation.

The transfer lines between the fermentation vessels and the storage vessels (racking pipelines) undergo a CIP clean on average once a day at a rate of 700 hl/h for 25 minutes (Van der Merwe, 2000). Therefore 292 hl of water is used per day for CIP cleaning of the racking lines and is discharged to the drains. Once a fermentation cycle is complete, the vessels undergo a CIP clean at a rate of 350 hl/h for 32 minutes. Since each fermentation vessel accommodates one brew, 187 hl of water per brew is used for CIP cleaning of the vessels and is discharged to the drains.

4.2.4 Racking

The centrifuge, located on the racking line, removes yeast from the green beer before maturation. To prevent damage to the centrifuge, water is continuously transferred through the shell of the centrifuge at a rate of 2 hl/h (Appelgrein, 2000). Therefore, on average, 48 hl of water is used per day and discharged to the drains. The water balance for racking is shown in Figure 4.6.

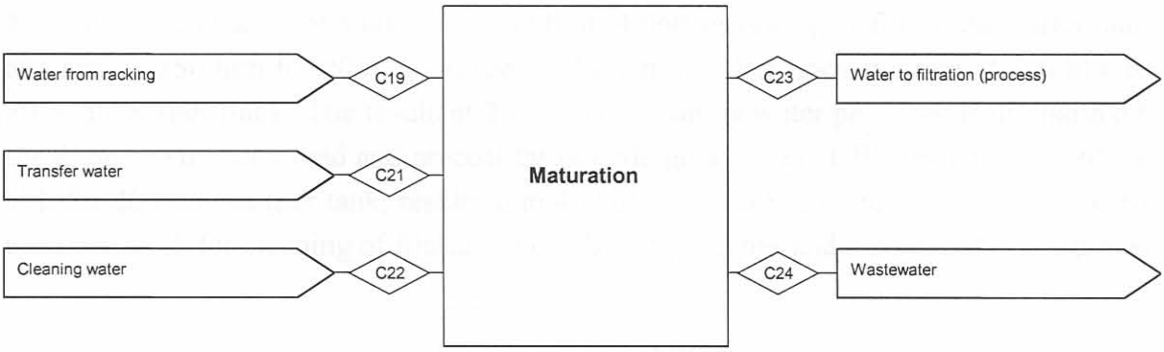
Stream	Volume [hl]	Frequency	Ave volume/week [hl/week]	Source ⊕
C15	2 153	per brew	68 896	-
C18	48	per day	240	S8
C19	2 153	per brew	68 896	C15
C20	48	per day	240	C18

⊕ Sources, other than streams, are presented at the end of each chapter.

Figure 4.6 The water balance for racking.

4.2.5 Maturation (storage vessels)

The water balance for maturation is shown in Figure 4.7. After the transfer of beer to the filtration system, water is used at a rate of 700 hl/h for a total time of 300 seconds to transfer any remaining beer in the lines to the filtration system (van der Merwe, 2000). Therefore 58 hl of water is utilised for beer transfer per brew and discharged to the drains. Each storage vessel accommodates one brew prepared by the brewhouse and after the completion of the maturation cycle, the vessels undergo a CIP clean at a rate of 350 hl/h for 32 minutes. The resultant 187 hl of water is discharged to the drains.



Stream	Volume [hl]	Frequency	Ave volume/week [hl/week]	Source ⊕
C19	2 153	per brew	68 896	-
C21	58	per brew	1 856	S3
C22	187	per brew	5 984	S4
C23	2 153	per brew	68 896	C19
C24	245	per brew	7 840	C21 + C22

⊕ Sources, other than streams, are presented at the end of each chapter.

Figure 4.7 The water balance for maturation (storage vessels).

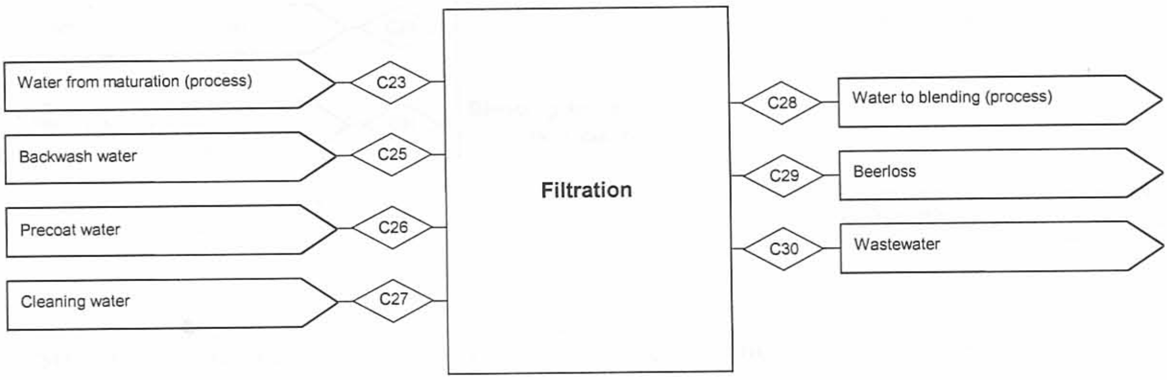
4.2.6 Filtration

The water balance for filtration is shown in Figure 4.8. The Rosslyn plant uses two kieselguhr filters for the filtration of the beer. Each filter treats 5 000 hl of beer before being backwashed resulting in approximately 14 backwashes in total for the two filters per week. Each filtration backwashing cycle uses 250 hl of water (Van der Merwe, 2000) and the resultant 3 500 hl of backwash water is discharged to the drains. According to Van der Merwe (2000), once the backwashing cycle is complete and before intake of the beer, 251 hl of water, containing body feed and precoat material, is used to precoat the filters and to prevent the uptake of oxygen by the beer. In total, 3 514 hl of water is utilised per week for precoating of the filters and is discharged to the drains.

It is estimated that 1,5% of the beer (on a volume basis) is lost during filtration (Naik, 2001). The resultant 32 hl of water per brew constitutes beerloss from the process and is discharged to the drains with the body feed and precoat material during the backwash cycle.

The filtration system at the Rosslyn plant consists of two filters, a pre and post filter buffer tank, a body feed and four precoat tanks and two filter transfer lines. The filters, pre and post filter buffer tanks and the two filter lines undergo a CIP clean once a week.

The filters are cleaned at a rate of 864 hl/h for 4 060 seconds (per filter), the buffer tanks at a rate of 350 hl/h for 20 minutes (per tank) and the filter lines at a rate of 700 hl/h for 20 minutes (per line). The resultant 2 649 hl of cleaning water per week is discharged to the drains. The body feed and precoat tanks undergo a weekly CIP clean at a rate of 240 hl/h for 20 minutes (per tank, resulting in 400 hl per week). In total, 3 049 hl of water is used per week for cleaning of filtration vessels and pipelines and discharged to the drains.



Stream	Volume [hl]	Frequency	Ave volume/week [hl/week]	Source ⊕
C23	2 153	per brew	68 896	-
C25	3 500	per week	3 500	S3
C26	3 514	per week	3 514	S3
C27	3 049	per week	3 049	S4
C28	2 121	per brew	67 872	C23 – C29
C29	32	per brew	1 024	S7
C30	-	-	10 063	C25 + C26 + C27

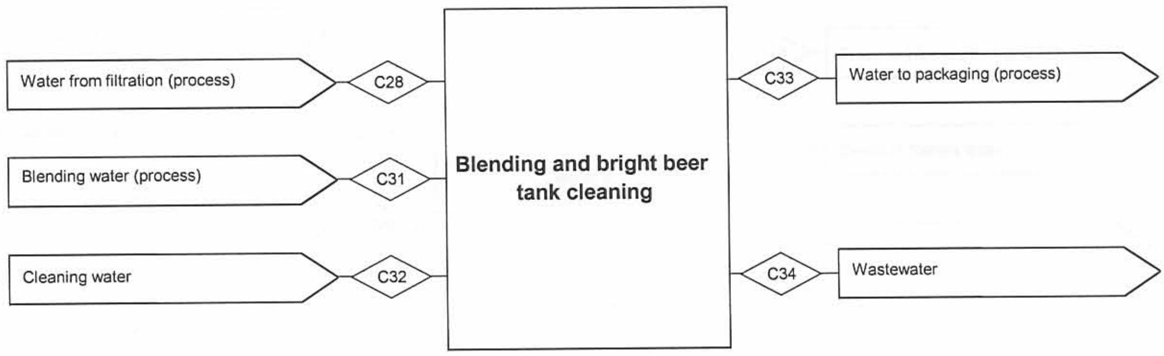
⊕ Sources, other than streams, are presented at the end of each chapter.

Figure 4.8 The water balance for filtration.

4.2.7 Blending and bright beer tank cleaning

The water balance for blending and bright beer tank cleaning (BBT) is shown in Figure 4.9. During the transfer of beer to the bright beer tanks (BBTs), deaerated carbonated water is blended with the beer at a ratio of 0,44 hl of water per hl of filtered beer (a mixture of process water and alcohol). Since the beer mixture contains 7,2 % alcohol (Roseveare, 2001), 2 286 hl of beer mixture is blended with 1 006 hl of deaerated water per brew, resulting in 3 292 hl of beer (containing 3 127 hl of water per brew) being transferred to the bright beer tanks per brew.

At the Rosslyn plant, the bright beer tanks can accommodate one brew and the vessels undergo a CIP clean after the transfer of beer to packaging. The water utilised for cleaning of the tanks is supplied by the cellars section at a rate of 350 hl/h for a total of 32 minutes. Therefore 187 hl of water is used per brew to clean the bright beer tanks and is discharged to the drains.



Stream	Volume [hl]	Frequency	Ave volume/week [hl/week]	Source ⊕
C28	2 121	per brew	67 872	-
C31	1 006	per brew	32 192	S1 + S9
C32	187	per brew	5 984	S4
C33	3 127	per brew	100 064	C28 + C31
C34	187	per brew	5 984	C33

⊕ Sources, other than streams, are presented at the end of each chapter.

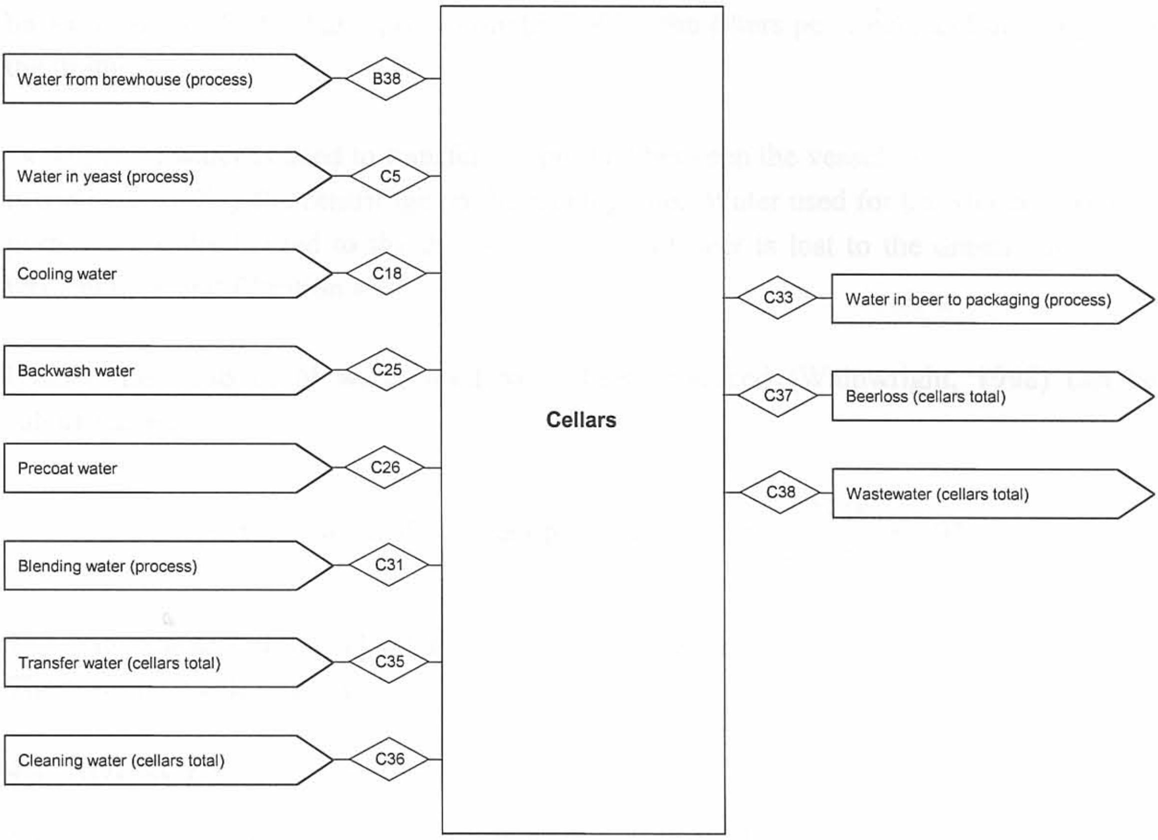
Figure 4.9 The water balance for blending and bright beer tank cleaning.

4.3 OVERALL MASS BALANCE OF THE CELLARS SECTION

The overall water balance over the cellars is shown in Figure 4.10.

A total of 92 848 hl water per week is introduced into the cellars section to produce 100 064 hl of normal gravity beer. This includes, *inter alia*, 32 672 hl per week of process water which is made up of:

- water in yeast (480 hl), and
- blending water (32 192 hl).



Stream	Volume per week (hl/week)	Source
B38	70 560	Section 4.2.1
C5	480	Section 4.2.2
C18	240	Section 4.2.4
C25	3 500	Section 4.2.6
C26	3 514	Section 4.2.6
C31	32 192	Section 4.2.7
C33	100 064	Section 4.2.7
C35	14 912	C1 + C6 + C11 + C12 + C21
C36	38 010	C2 + C7 + C8 + C13 + C14 + C22 + C27 + C32
C37	3 168	C16 + C29
C38	60 176	C4 + C10 + C17 + C20 + C24 + C30 + C34

Figure 4.10 The overall water balance for the entire cellars section.

38 010 hl of water is used for cleaning of vessels and lines and forms part of the wastewater discharged to the drains. During filtration, 7 014 hl of water is used for

backwashing (3 500 hl) and precoating (3 514 hl) the filters per week, and discharged to the drains.

14 912 hl of water is used to transfer the product between the vessels and 240 hl of water is used for cooling the centrifuge on the racking line. Water used for transfer and cooling purposes are discharged to the drains. 3 168 hl of beer is lost to the drains during the fermentation and filtration stages.

Finally, the ratio of hl water used to hl beer produced (Wainwright, 1998) can be calculated as:

$$(\text{Ratio of water used : beer produced})_{\text{cellars}} = \frac{92848}{100064} = 0{,}93$$

The water balance in this chapter does not include water for washdown and other losses. These streams will be considered in Chapter 6.

4.4 SOURCES

The sources used within this chapter for calculating the different water balances over the cellars are presented below.

Source	Reference
S6	Bradfield, P. (2001) "Operation in the SAB Rosslyn Cellars Section", Personal communication, Rosslyn plant, Pretoria.
S7	Naik, T. (2000) "Raw Materials used at the Rosslyn Plant", Personal communication, Rosslyn Brewery, Pretoria.
S8	Appelgrein, J. (2000) "Cooling of the Centrifuge on the Racking Line", Personal communication, Rosslyn plant, Pretoria.
S9	Roseveare, J. (2001) "Solids Content in the Beer at Different Stages of Production", Personal communication, Rosslyn plant, Pretoria.

CHAPTER 5

PACKAGING

5.1 INTRODUCTION AND BACKGROUND

The Rosslyn packaging section consists of five production lines of which three are quart lines (line 1, 4 and 5), one is a can line (line 2) and one is a handy line (line 3). The quart, can and handy packaging lines will be addressed separately due to differences in machines utilised on the lines and subsequent different water requirements. Due to the simplicity of certain processes on the production lines, certain water balances will also be combined.

5.1.1 Quart lines (returnable bottles)

The quart lines pack beer into 750 ml bottles, mainly returned from trade (new bottles are periodically introduced onto the production lines to replace older bottles). The hygiene of the returnable bottles is poor and good cleaning is vital to ensure that contamination of the beer is avoided. Each of the production lines is capable of bottling a specified volume of beer. At the Rosslyn plant, lines 1, 4 and 5 are rated to pack the following volumes of beer per hour:

Line 1 – 315 hl/h
Line 4 – 315 hl/h
Line 5 – 450 hl/h

The equipment used on each line may differ in age and manufacturer. For the purposes of this thesis, an average water consumption for the three lines will be assumed. As shown in Figure 2.4, a quart line consists of a depalletiser, a decrowner, an uncrater, a crate washer, a bottle washer, an empty bottle inspector, a filler, a crowner, a pasteuriser, a labeller, a recrater and a palletiser.

Depalletiser, decrowner and uncrater

The depalletiser, decrowner and uncrater use water for general cleaning purposes. Operators use high pressure hoses to clean the machinery and the surrounding areas.

Crate washer

The crate washer consists of numerous compartments (or zones) containing cleaning water to ensure the thorough cleaning of the crates. Two of the compartments in the crate washer (the final rinse and pre-wash compartments), require clean water to be supplied continuously during the washing process to ensure that effective cleaning takes place. This water is discharged to the drains. The cleaning water in the other compartments of the crate washer is analysed weekly and if the water quality deteriorates below a certain level, the water contained within such a compartment will be discharged to the drains and replaced with potable water.

Bottle washer

Bottles returned from trade are cleaned in the bottle washer. As with the crate washer, the bottle washer also consists of several compartments where the bottles are presoaked in one or more water baths at increasing temperatures, passed through hot caustic baths, rinsed with caustic, hot water, cold water and eventually rinsed with potable water. As the bottles pass through the compartments, water is carried over to the following compartment by either adhering to a bottle's surface or by being trapped inside a bottle. Water is added on a continuous basis to ensure that the levels in the bottle washer remain balanced. In the final compartment of the washer, the bottles are continuously rinsed with potable water. This water is recycled to the first compartment of the bottle washer from where it is discharged to the drains after use. In general, the flowrate into the washer is 21 m^3/h (Schumacher, 2000).

The water used within the bottle washer must be clean enough to ensure that the bottles are cleaned sufficiently and the water within the compartments is analysed on a weekly basis. Should the quality of the water within a compartment be below the prescribed quality level, the water within that compartment is discharged to the drains. The compartment is then filled to the correct volume with potable water.

Empty bottle inspector

Prior to being filled with beer, the bottles are inspected for any cracks or dirt, which may not have been removed in the washer. Water for this machine is mainly used to ensure that the bottles are wet before being inspected to reduce the influence of scuff marks on inspection efficiency. After the bottles have been inspected, they are conveyed to the filler. The empty bottle inspector (EBI) and the surrounding area undergo a general clean on a shift basis.

Filler and crowner

Before the bottles are filled with the beer (which is stored in the BBT vessels), deaerated water is transferred through the filling lines to displace any air out of the lines. The lines are simultaneously cooled to ensure that the temperature of the beer is not altered which would cause CO_2 to be released from the beer, adversely affecting the filling process.

The first stage of filling is the removal of the air residing in the bottle by applying a vacuum, created by a vacuum pump. At the Rosslyn plant, water is used to cool the vacuum pump (the pump may lose efficiency with increasing heat), as well as to create a water seal and therefore prevent air from entering the bottle. The water used by the vacuum pump is discharged to the drains.

Before the bottles are closed or crowned, a fine jet of water is sprayed into the bottle causing the beer to foam which in turn displaces air from the headspace above the beer. The bottles are closed immediately thereafter and rinsed with water to remove traces of beer. Should a bottle burst during filling, a set of sprays is activated which flushes the glass (also termed cullet) and the beer out of the area in which the burst occurred.

On completion of beer transfer, deaerated water is transferred through the line to transfer any beer remaining in the line to the filler. If there is a change in the brand of beer being packed, the pipeline is rinsed with water to remove traces of the previous brand. The pipelines, transferring beer to the filler, and the filler undergo a CIP clean on a weekly basis.

Pasteuriser

Tunnel pasteurisation is used at the Rosslyn plant. The pasteuriser contains several compartments filled with water at different temperatures. As discussed in Section 2.3.4.1, water is recycled between different compartments for either heating or cooling of the bottles. This is to ensure optimal energy and water usage. However, as the bottles are conveyed through the pasteuriser, water is carried over by the bottles to the next compartment, thus resulting in decreasing water levels within the pasteuriser compartments. Water is added to the pasteuriser to compensate for these decreasing levels within the compartments. The final rinse compartment of the pasteuriser uses water from the cooling towers to cool down the bottles which is then returned back to the cooling towers. The spray bars inside the pasteuriser are flushed with water, with the aid of high-pressure hoses, to ensure cleanliness. When the quality of the water contained within the compartments of the pasteuriser deteriorate to undesirable levels (due to, *inter alia,* bursting bottles), the water in these compartments is discharged to the drains and replaced with potable water.

Labeller, recrater and palletiser

The bottles are conveyed to the labeller where the labels are applied to the bottles. The labeled bottles are then conveyed to the recrater where they are placed into crates containing twelve bottles. Full crates are placed onto pallets which are then packed onto trucks and transported to distribution depots. The machines only use water for general cleaning purposes.

Chain lube

The conveyors are lubricated with a mixture of chain lube and water to reduce friction between the moving parts of the conveyor and between the conveyor and the bottles. It is estimated that 0,028 litre of chain lube is used per hl of beer packed and that the concentration of chain lube in the mixture is 0,4 % (Davis, 2000). Therefore the volume of water used for lubricating the conveyors is estimated to be 7 litre per hl of beer packed.

5.1.2 Can and handy lines (nonreturnable containers)

The Rosslyn plant has one can line (for 340 ml and 450 ml cans) and one handy line (340 ml bottles). The lines at SA Breweries' Rosslyn plant are rated to pack the following volumes of beer per hour:

Line 2 – 170 hl/h
Line 3 – 408 hl/h

As shown in Figure 2.5, a nonreturnable container line consists of the machine depalletiser, rinser, filler, seamer/crowner, pasteuriser, shrinkwrapper, traypacker and palletiser. The following analysis is based on average operations at the Rosslyn Plant.

Machine depalletiser

Water is used for general cleaning purposes of the machine. The operator uses high pressure hoses to clean the machinery and the surrounding areas.

Rinser

The bottles and cans are sprayed for a brief period of time with clean water to remove dust which may have collected within the container. Water runs continuously from the rinser sprays to the drains. Water is also used for the general cleaning of the rinser and surrounding areas.

Filler and seamer/crowner

Similar to the quart lines, deaerated water is transferred through the filling lines prior to and on completion of beer transfer. Water is also used to CIP clean the beer lines and filler to ensure that no build-up of dirt occurs at any time.

Jetting with water also occurs on the nonreturnable bottle line to displace air from the airspace above the beer. However, unlike bottle filling, can filling does not require jetting of water on completion of the filling process. Instead a stream of CO_2 is passed into the can to break the beer bubbles. Once the cans have been filled and closed or seamed (or the bottles filled and crowned), they are rinsed with water to remove traces of beer. In addition, water is also used for general cleaning purposes.

Pasteuriser

The operation of the pasteuriser used on the can and handy lines is similar to that for the quart lines. Water is also used to make up the water levels in the compartments due to the carry over of water by the cans and bottles. The final compartment of the handy line uses water from the cooling towers to cool the bottles exiting the pasteuriser. This water is circulated back to the cooling towers and the levels in the cooling tower made up with potable water. However, the final compartment on the can line uses potable water to cool the cans exiting the pasteuriser and is discharged directly to the drains. The spray bars inside the pasteuriser are flushed with water, with the aid of high-pressure hoses, to ensure cleanliness. As discussed in Section 2.3.4.2, when the quality of the water used in the pasteuriser deteriorates below the relevant standard (Volmer, 2001), the water is discharged to the drains and replaced with water from the main supply. This normally occurs on a weekly basis.

Shrinkwrapper, traypacker and palletiser

As with the machine depalletiser, water is used for general cleaning purposes of these machines.

Chain lube

Similer to the returnable bottle line, a mixture of chain lube and water is also used on the nonreturnable container lines to lubricate the conveyors and reduce the friction between the moving parts of the conveyor and between the conveyor and the containers. The water used for lubricating the conveyors is, similar to Section 5.1.1, estimated at 7 l/hl of beer packed.

5.2 WATER USE IN THE PACKAGING SECTION

The general water balance over the packaging section is shown in Figure 5.1. The packaging section packs 100 064 hl of beer per week (Section 4.3), prepared by the brewing section, into returnable bottles and nonreturnable cans and bottles.

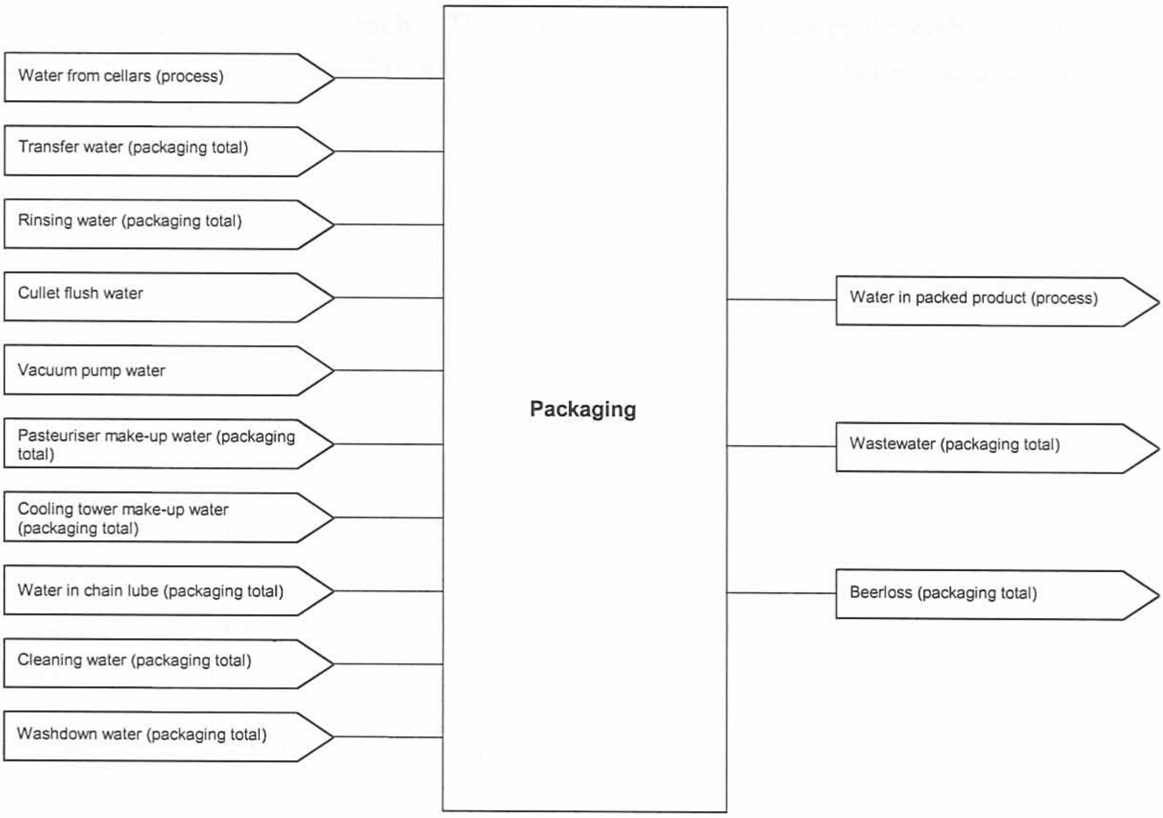


Figure 5.1 The general water balance over the packaging section.

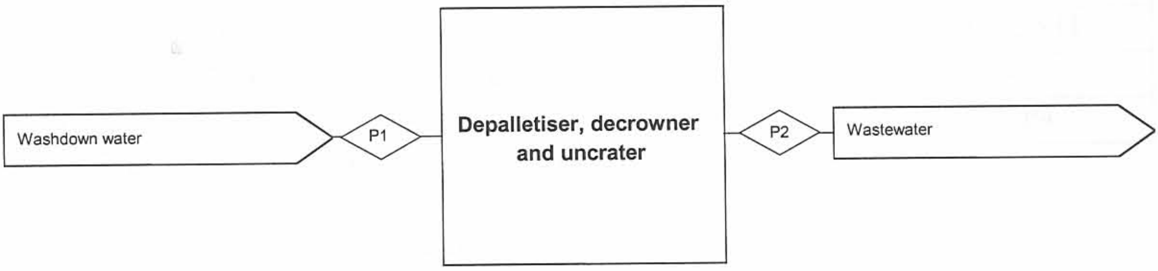
5.2.1 Water use on the quart line

Two quart lines at the Rosslyn plant are rated to pack 315 hl/h of beer while the third quart line is capable of packing 450 hl/h of beer. In terms of this thesis, an average line rating of 360 hl/hour for the three quart lines will be used. Given that the average volume of beer packed by all three lines per day is 14 835 hl (SAB, 2001), a single line packs, on average, 4 945 hl/day. With an average line rating of 360 hl/hour and an average line efficiency of 73,4 % (SAB, 2001), a line is active for approximately 19 hours per day.

A distinction will also be made in this thesis between cleaning and washdown water. Cleaning water will relate to water used for cleaning purposes inside a machine, whereas washdown water will refer to water used for cleaning machines on the outside.

Depalletiser, decrowner and uncrater.

The water balance for the depalletiser, decrowner and uncrater is shown in Figure 5.2. The depalletiser, decrowner and uncrater are washed daily with high-pressure hoses for approximately one hour each and undergo a thorough clean on a weekly basis for approximately two hours each. The average flowrate of water through these hoses is assumed to be 5 000 l/h and therefore 1 050 hl of water is used per week and discharged to the drains (SAB, 2001).



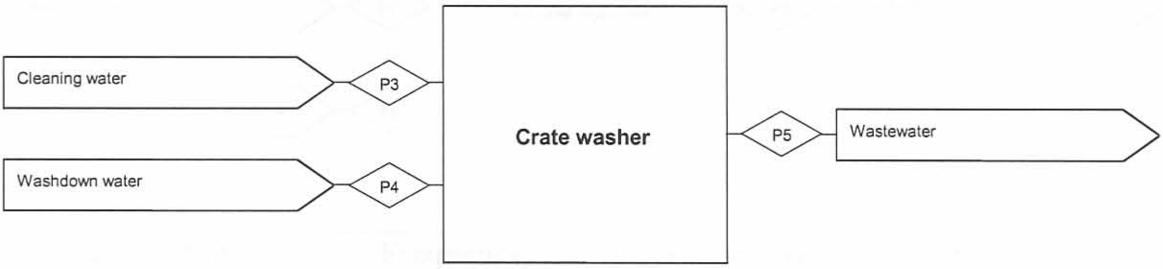
Stream	Volume [hl]	Frequency	Ave volume/week [hl/week]	Source ⊕
P1	1 050	per week	1 050	S4
P2	1 050	per week	1 050	P1

⊕ Sources, other than streams, are presented at the end of each chapter.

Figure 5.2 Water balance for the depalletiser, decrowner and uncrater (quart line).

Crate washer

The water balance for the crate washer is shown in Figure 5.3. To ensure that the water used to clean the crates remains within acceptable standards, an average of 58 hl/h of dirty water is discharged to the drains and replaced with potable water (SAB, 2001). If the machine is in operation 19 hours per day, an average of 5 510 hl of water per week is discharged to the drains. In addition, water (and chemicals) in specified compartments of the crate washer, with an average volume of approximately 96 hl (Volmer, 2000), is discharged once a week to the drains as per a predefined schedule and replaced with potable water. Therefore, 5 606 hl of water (in total) is used per week to ensure thorough cleaning of the crates and discharged to the drains. The crate washer and surrounding area are also washed with high pressure hoses by an operator for an average of 6 hours per week. If it is assumed that the average flowrate through these hoses is 5 000 l/h, then 300 hl of water is used for washdown of the crate washer.



Stream	Volume [hl]	Frequency	Ave volume/week [hl/week]	Source ⊕
P3	5 606	per week	5 606	S10 and S11
P4	300	per week	300	S4
P5	5 906	per week	5 906	P3 + P4

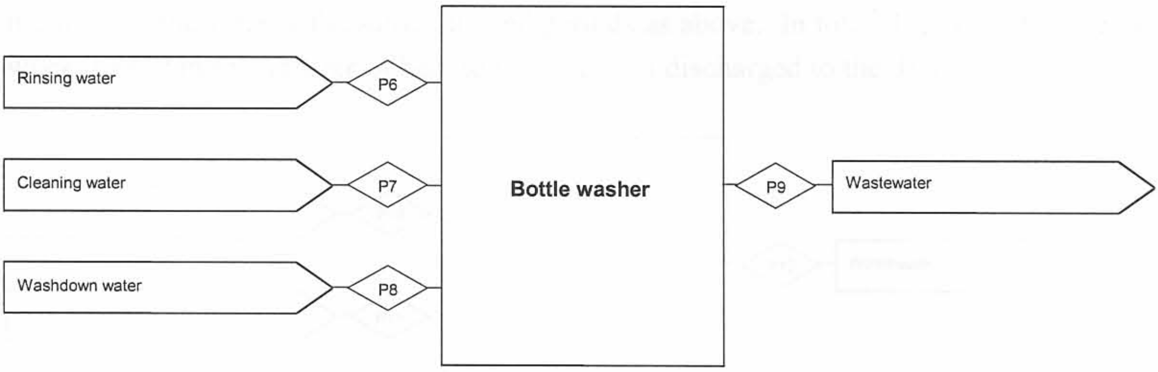
⊕ Sources, other than streams, are presented at the end of each chapter.

Figure 5.3 Water balance for the crate washer (quart line).

Bottle washer

The water balance over the bottle washer is shown in Figure 5.4. A continuous flow of water is used to rinse the bottles in the last compartment of the bottle washer and to maintain the levels in the bottle washer. The average flowrate of water to the final rinse compartment of the bottle washer is 210 hl/h (SAB, 2001) and if the machine is in operation for 19 hours per day, 3 990 hl of water is discharged to the drains per day.

A predetermined volume of water is used on a daily (42 hl) and on a weekly (304 hl) basis for cleaning purposes (Volmer, 2000). Therefore 514 hl of water is discharged to the drains per week to ensure that the water within the compartments remains within acceptable standards. The bottle washer is also washed for an average of 6 hours per week with high pressure hoses and if the flowrate through a hose is assumed to be 5 000 l/h, then 300 hl of water is used to washdown the bottle washer.



Stream	Volume [hl]	Frequency	Ave volume/week [hl/week]	Source ⊕
P6	3 990	per day	19 950	S10
P7	514	per week	514	S11
P8	300	per week	300	S4
P9	-	-	20 764	P6 + P7 + P8

⊕ Sources, other than streams, are presented at the end of each chapter.

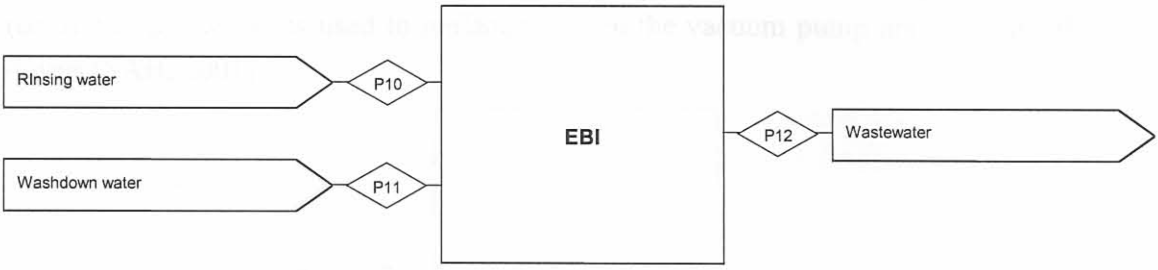
Figure 5.4 Water balance over the bottle washer (quart line).

Empty bottle inspector

The water balance over the empty bottle inspector (EBI) is shown in Figure 5.5. The flowrates of unmeasured streams were determined from plant trials conducted during November 2000 to approximate water volumes used in the EBI (Van der Merwe, 2000). From these trials the average flowrate through the water sprays of the EBI was found to be 0,18 hl/h. Therefore, assuming the line is operated for 19 hours per day, 3 hl of rinsing water is discharged to the drains per day. The EBI is washed, on average, once a week for approximately 30 minutes with high pressure hoses and if the flowrate through a high pressure hose is assumed to be 5 000 l/h, 25 hl of water per week is used for washdown purposes.

Filler

The water balance over the filler is shown in Figure 5.6. 24 725 hl of beer per week (4 945 hl/day) is transferred from the BBTs to the filler per line. Before the transfer of beer from the BBTs to the filler, deaerated water is used to displace air in the filler lines at a rate of 370 hl/h for 10 minutes (SAB, 2001). This practice occurs, on average, twice a day and the resultant 617 hl per week of deaerated water is discharged to the drains. On completion of the beer transfer, deaerated water is used to transfer any beer remaining in the lines to the filler at the same rate and periods as above. In total, 1 234 hl of water per week is used in the transfer of beer to the filler and discharged to the drains.



Stream	Volume [hl]	Frequency	Ave volume/week [hl/week]	Source ⊕
P10	3	per day	15	S12
P11	25	per week	25	S4
P12	-	-	40	P10 + P11

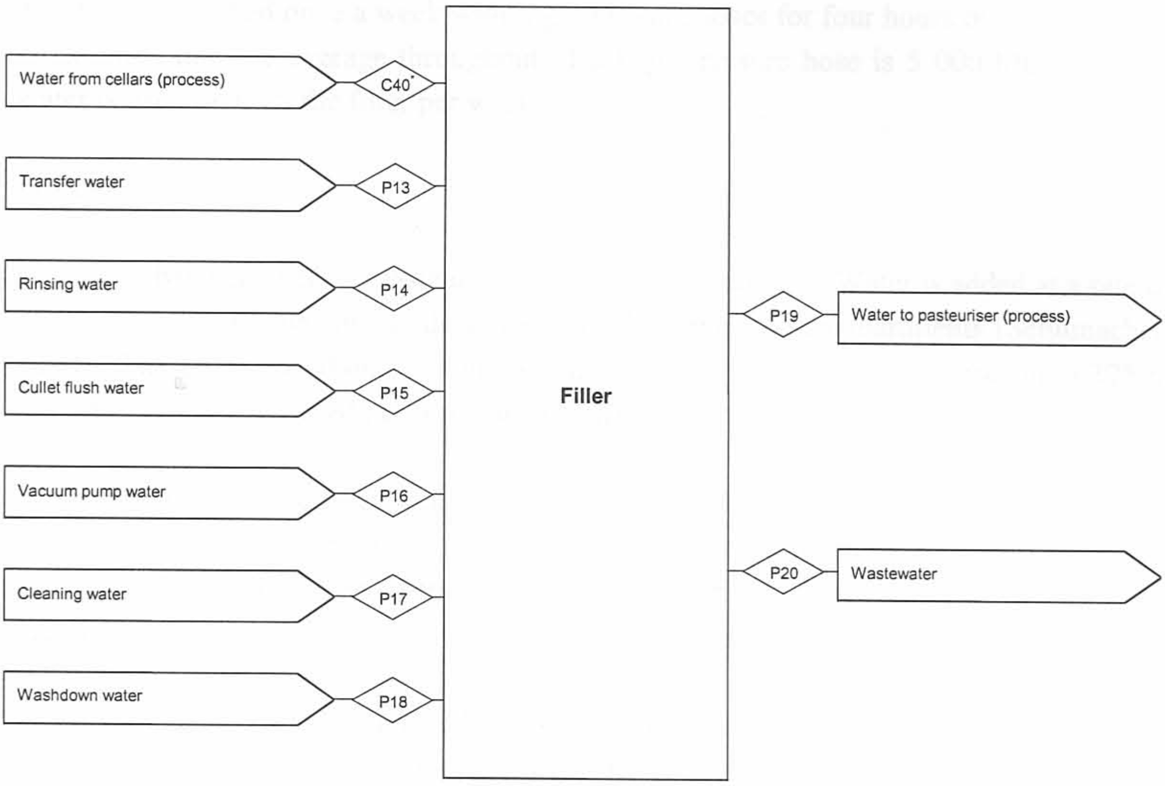
⊕ Sources, other than streams, are presented at the end of each chapter.

Figure 5.5 Water balance over the EBI (quart line).

After the bottles have been filled with beer, a fine jet of water is sprayed into the bottles to displace air from the headspace of the bottle. During the plant trials of November 2000, the flowrate of this water was found to be 0,08 hl/hour on average and subsequently 7,6 hl of water per week per line is discharged to the drains. This volume is an order of magnitude lower than that of the other water volumes calculated in this thesis and is therefore assumed to be negligible. After the bottles have been filled and crowned, they are rinsed by five water sprays with an average flowrate, calculated from plant trials, of 2,85 hl/h per spray. Therefore, assuming that the sprays are in operation for 19 hours per day, the volume of water lost due to rinsing is 1 354 hl per week and discharged to the drains.

Should a bottle burst during filling, a set of sprays is activated which flushes the area in which the bottle burst. The average amount of cullet (broken bottles) generated during filling per week per line is 189,2 kg, which equates to 376 bottles (SAB, 2001). The average flowrate through the water sprays is 250 hl/h and the sprays are activated for approximately 5 seconds per bottle breakage (Schumacher, 2000). Therefore the average volume of water used per week to flush the filler due to broken bottles is 131 hl.

To remove any air residing in the bottles, a vacuum is applied through a vacuum pump. Water is used to create the vacuum and once the temperature of the water becomes too high, the hot water is replaced and discharged to the drains. An average of 62 hl per day (or 310 hl per week) is used to replace water in the vacuum pump and discharged to the drains (SAB, 2001).



Stream	Volume [hl]	Frequency	Ave volume/week [hl/week]	Source ⊕
C40*	24 725	per week	24 725	Section 4.3
P13	1 234	per week	1 234	S4
P14	1 354	per week	1 354	S12
P15	131	per week	131	S13
P16	310	per week	310	S10
P17	56	per week	56	S14
P18	200	per week	200	S4
P19	24 725	per week	24 725	C40
P20	3 285	per week	3 285	P13 + P14 + P15 + P16 + P17 + P18

⊕ Sources, other than streams, are presented at the end of each chapter. * part of C40.

Figure 5.6 Water balance over the filler (quart line).

The beer lines undergo a CIP clean once every second week at a rate of 450 hl/h. The CIP cycle continues for approximately 40 minutes, of which 15 minutes of flow is expected to discharge to the drains (Myoli, 2000). Therefore the average volume of water used to CIP the lines for a week is 56 hl.

The filler is washed once a week with high pressure hoses for four hours on average. If it is assumed that the average throughput of a high-pressure hose is 5 000 l/h, 200 hl of water is used to wash the filler per week.

Pasteuriser

The water balance over the pasteuriser is shown in Figure 5.7. Water is added at a rate of 35 hl/h to compensate for the decreasing levels within the compartments (Schumacher, 2000). Therefore, based on 19 hours per day and five days per week operation, 3 325 hl of make-up water is added per week and discharged to the drains.

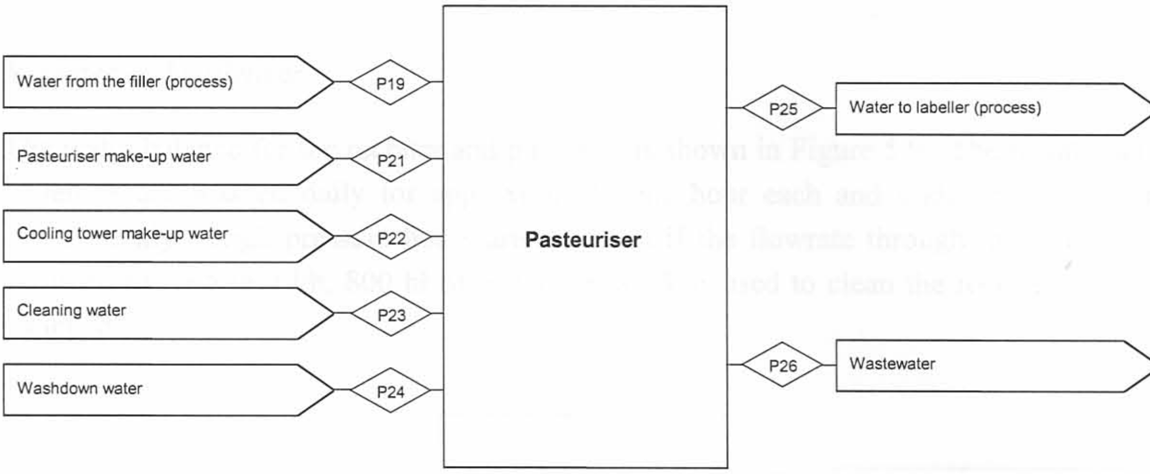
Water is also circulated between the cooling towers and the pasteuriser. On average, a flow of 24 hl/h is expected to make-up for losses incurred (SAB, 2001). Therefore, assuming that the line is in operation for 19 hours per day, the average volume of water required to make-up the volumes in the cooling towers is 2 280 hl per week.

When the quality of the water within the pasteuriser compartments deteriorates below a certain level, it is discharged to the drains. The average volume of cleaning water added per week is 128 hl (SAB, 2001).

The pasteuriser is washed daily for two hours and undergoes a thorough clean once a week for an average of five hours. High-pressure hoses are used to clean the pasteuriser and if it is assumed that the average throughput of a hose is 5 000 l/h, then the average volume of water used to clean the pasteuriser is 750 hl per week.

Labeller

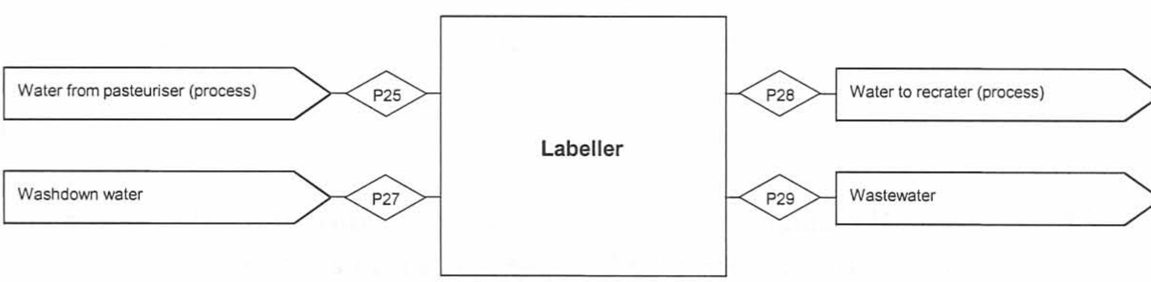
The water balance over the labeller is shown in Figure 5.8. The labeller is washed daily for approximately one hour and undergoes a thorough clean weekly for approximately two hours. High-pressure hoses are used to clean the labeller and if the flowrate through these hoses is assumed to be 5 000 l/h, 350 hl of water is used per week.



Stream	Volume [hl]	Frequency	Ave volume/week [hl/week]	Source ⊕
P19	24 725	per week	24 725	-
P21	3 325	per week	3 325	S13
P22	2 280	per week	2 280	S10
P23	128	per week	128	S10
P24	750	per week	750	S4
P25	24 725	per week	24 725	P19
P26	6 483	per week	6 483	P21 + P22 + P23 + P24

⊕ Sources, other than streams, are presented at the end of each chapter.

Figure 5.7 Water balance over the pasteuriser (quart line).



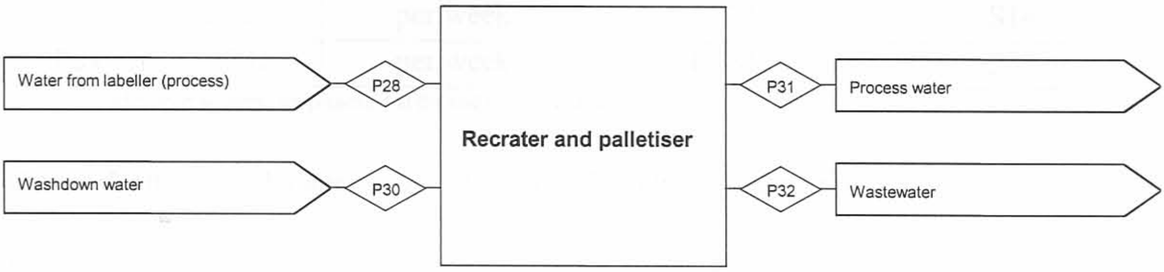
Stream	Volume [hl]	Frequency	Ave volume/week [hl/week]	Source ⊕
P25	24 725	per week	24 725	-
P27	350	per week	350	S4
P28	24 725	per week	24 725	P25
P29	350	per week	350	P27

⊕ Sources, other than streams, are presented at the end of each chapter.

Figure 5.8 Water balance over the labeller (quart line).

Recrater and palletiser

The water balance for the recrater and palletiser is shown in Figure 5.9. The recrater and palletiser are washed daily for approximately one hour each and undergo a thorough clean weekly. High pressure hoses are used and if the flowrate through these hoses is assumed to be 5 000 l/h, 800 hl of water per week is used to clean the recrater and the palletiser.



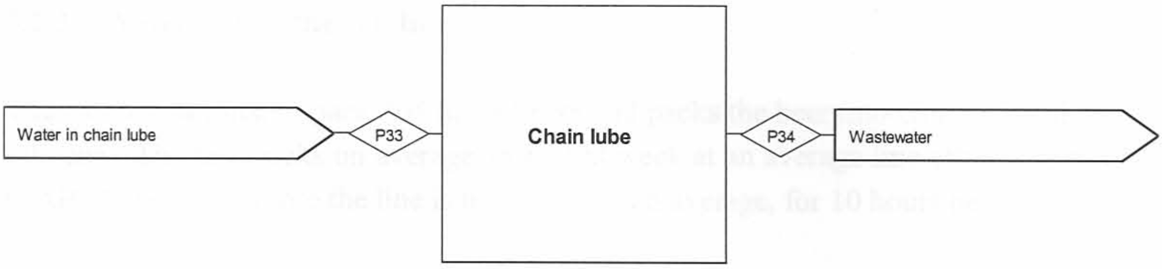
Stream	Volume [hl]	Frequency	Ave volume/week [hl/week]	Source ⊕
P28	24 725	per week	24 725	-
P30	800	per week	800	S4
P31	24 725	per week	24 725	P28
P32	800	per week	800	P30

⊕ Sources, other than streams, are presented at the end of each chapter.

Figure 5.9 Water balance over the recrater and the palletiser (quart line).

Chain lube

The water balance associated with chain lube is shown in Figure 5.10. To reduce friction between the moving parts of the conveyor and between the conveyor and the bottles, a chain lube mixture is added. The volume of water used for lubrication is 1 731 hl, based on 7 litre of water per hl of beer packed (see Section 5.1.1).



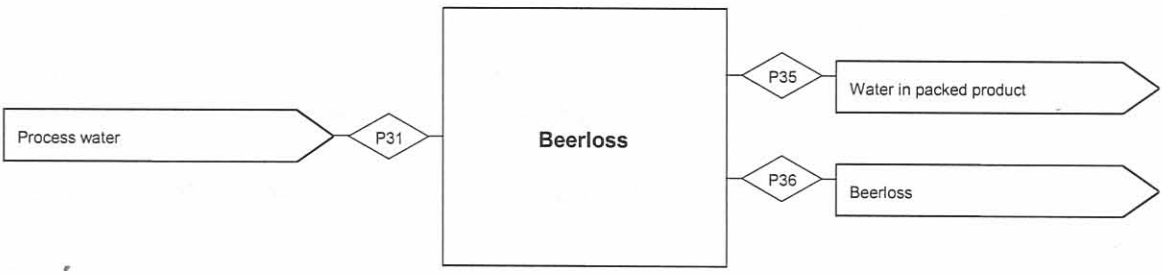
Stream	Volume [hl]	Frequency	Ave volume/week [hl/week]	Source ⊕
P33	1 731	per week	1 731	S14
P34	1 731	per week	1 731	P33

⊕ Sources, other than streams, are presented at the end of each chapter.

Figure 5.10 Water balance associated with chain lube (quart line).

Beerloss

The water balance associated with the beer lost to the drains on the returnable bottle line is shown in Figure 5.11. During the packing process, beerlosses are inevitable and these losses are discharged to the drains. It is expected that, on average, 1,25 % of the beer packed is lost to the drains (Davis, 2000). Therefore, if one packaging line packs 24 725 hl of beer per week, 309 hl of beer is lost to the drains per week per line.



Stream	Volume [hl]	Frequency	Ave volume/week [hl/week]	Source ⊕
P31	24 725	per week	24 725	-
P35	24 416	per week	24 416	P31 - P36
P36	309	per week	309	S14

⊕ Sources, other than streams, are presented at the end of each chapter.

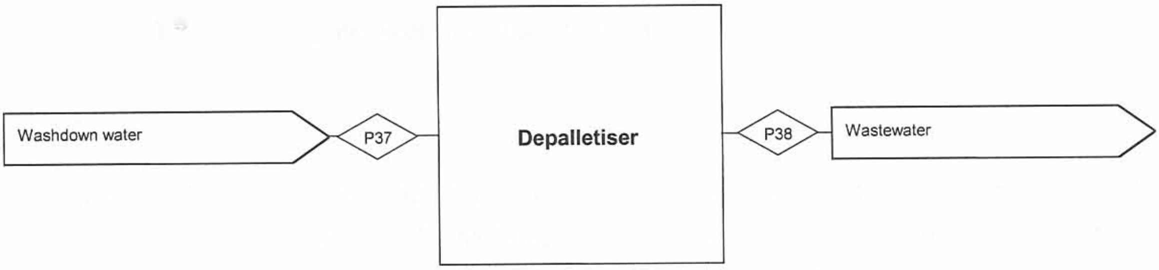
Figure 5.11 Water balance associated with beer lost to the drains (quart line).

5.2.2 Water use on the can line

The can line is rated to pack 408 hl/h of beer and packs the beer into either 450 ml or 340 ml cans. The line packs on average 15 839 hl/week at an average line efficiency of 80% (SAB, 2001). Therefore the line is in operation, on average, for 10 hours per day.

Depalletiser

The water balance over the depalletiser is shown in Figure 5.12. The depalletiser is washed daily with high-pressure hoses for approximately one hour and undergoes a thorough clean on a weekly basis for approximately two hours. The average flowrate of water through these hoses is assumed to be 5 000 l/h and therefore 350 hl of water is used per week and discharged to the drains (SAB, 2001).



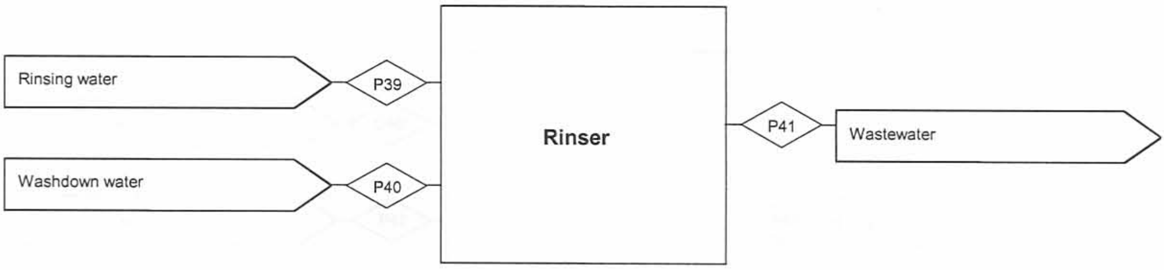
Stream	Volume [hl]	Frequency	Ave volume/week [hl/week]	Source ⊕
P37	350	per week	350	S4
P38	350	per week	350	P37

⊕ Sources, other than streams, are presented at the end of each chapter.

Figure 5.12 Water balance over the depalletiser (can line).

Rinser

The water balance over the rinser is shown in Figure 5.13. The rinser sprays water into the cans at a rate of 24 hl per hour (Myoli, 2000) and this water is discharged to the drains. Assuming the line is active for 10 hours per day, the volume of water used to rinse the cans is 1 200 hl per week. The rinser is washed for approximately five hours per week with high-pressure hoses. Since the flowrate through these hoses is assumed to be 5 000 l/h, 250 hl of water is used to wash the rinser per week.



Stream	Volume [hl]	Frequency	Ave volume/week [hl/week]	Source ⊕
P39	1 200	per week	1 200	S14
P40	250	per week	250	S4
P41	1 450	per week	1 450	P39 + P40

⊕ Sources, other than streams, are presented at the end of each chapter.

Figure 5.13 Water balance over the rinser (can line).

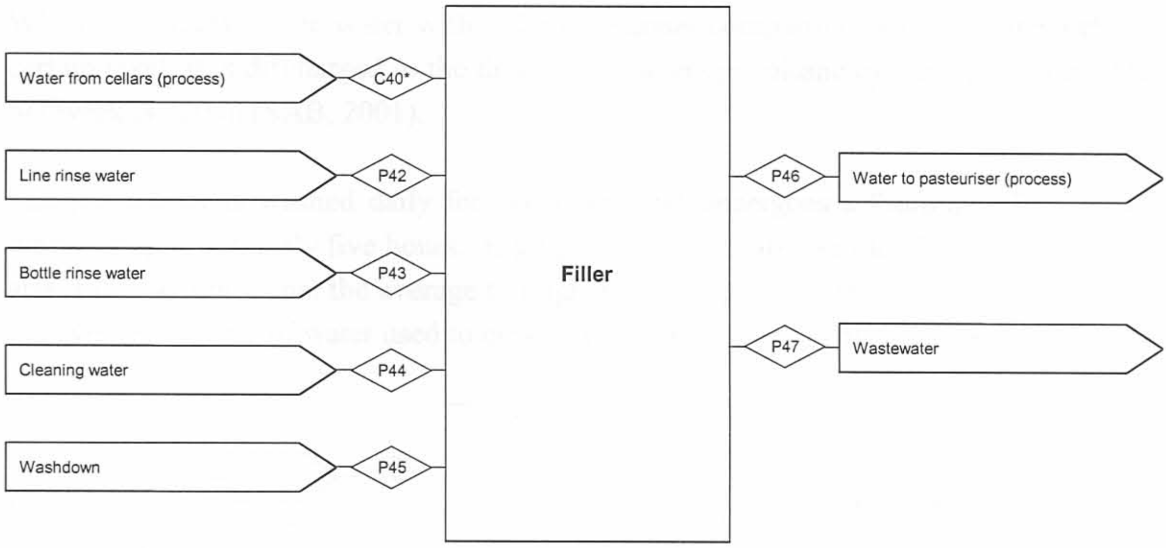
Filler

The water balance over the can line filler is shown in Figure 5.14. From Section 5.2.2 15 839 hl of beer per week (3 168 hl/day) is transferred to the filler on the can line. Before the transfer of beer from the BBT's to the filler, deaerated water is used to displace air in the filler lines at a rate of 408 hl/h for 10 minutes. This practice occurs, on average, once per day and the resultant 340 hl per week of deaerated water is discharged to the drains. On completion of the beer transfer, deaerated water is used to transfer any beer remaining in the lines to the filler, at the same rate and periods as above. In total, 680 hl of water per week is used in the transfer of beer to the filler and discharged to the drains.

After the cans have been filled and seamed, they are rinsed at an average rate of 5 hl/h (Myoli, 2000). Therefore, if the line is in operation for 10 hours per day, 250 hl of water is used per week to rinse the cans.

The beer lines undergo a CIP once every second week at a rate of 165 hl/h. The CIP cycle continues for approximately 40 minutes, of which 15 minutes of flow is expected to discharge to the drains (Myoli, 2000). Therefore the average volume of water used to CIP the lines per week is 21 hl.

The filler is washed once a week with high-pressure hoses for four hours on average. If it is assumed that the average throughput of a high-pressure hose is 5 000 l/h, 200 hl of water is used to wash the filler per week.



Stream	Volume [hl]	Frequency	Ave volume/week [hl/week]	Source ⊕
C40*	15 839	per week	15 839	-
P42	680	per week	680	S4
P43	250	per week	250	S14
P44	21	per week	21	S14
P45	200	per week	200	S4
P46	15 839	per week	15 839	C40
P47	1 151	per week	1 151	P42 + P43 + P44 + P45

⊕ Sources, other than streams, are presented at the end of each chapter. * part of C40.

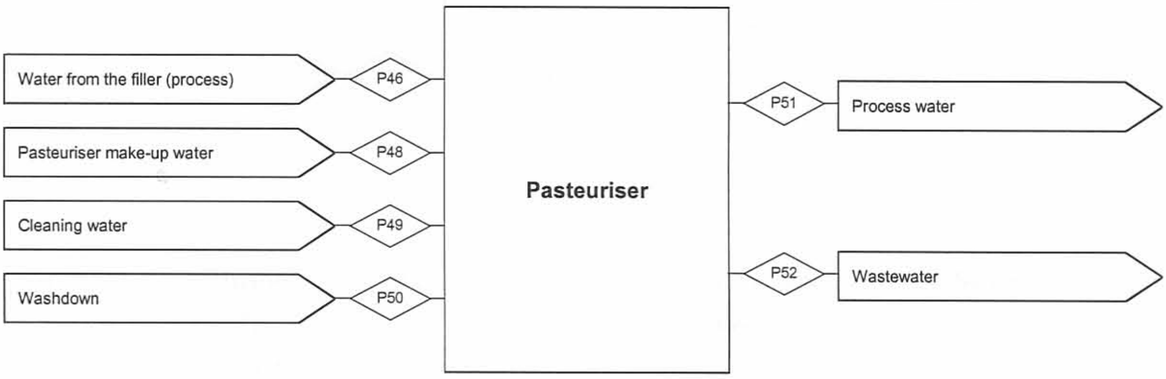
Figure 5.14 Water balance over the filler (can line).

Pasteuriser

The water balance over the pasteuriser on the can line is shown in Figure 5.15. Unlike the pasteurisers used on the bottle lines, the pasteuriser used on the can line does not recycle water back to the cooling towers. Water is transferred to the final compartment of the pasteuriser at a rate of 294 hl/h (SAB, 2001), resulting in 14 700 hl of water discharged to the drains per week. In addition, water is also added to the pasteuriser at a rate of 40 hl per hour (or 2 000 hl per week) to compensate for the carry over of water by the cans (Schumacher, 2000). In total, 16 700 hl of pasteuriser make-up water is added to the pasteuriser per week and discharged to the drains.

When the quality of the water within the pasteuriser compartments deteriorates below a certain level, it is discharged to the drains. The average volume of cleaning water added per week is 230 hl (SAB, 2001).

The pasteuriser is washed daily for two hours and undergoes a thorough clean once a week for approximately five hours. High-pressure hoses are used to clean the pasteuriser and if it is assumed that the average throughput of a high-pressure hose is 5 000 l/h, then the average volume of water used to clean the pasteuriser is 750 hl per week.



Stream	Volume [hl]	Frequency	Ave volume/week [hl/week]	Source ⊕
P46	15 839	per week	15 839	-
P48	16 700	per week	16 700	S9
P49	230	per week	230	S9
P50	750	per week	750	S4
P51	15 839	per week	15 839	P48
P52	17 680	per week	17 680	P48 + P49 + P50

⊕ Sources, other than streams, are presented at the end of each chapter.

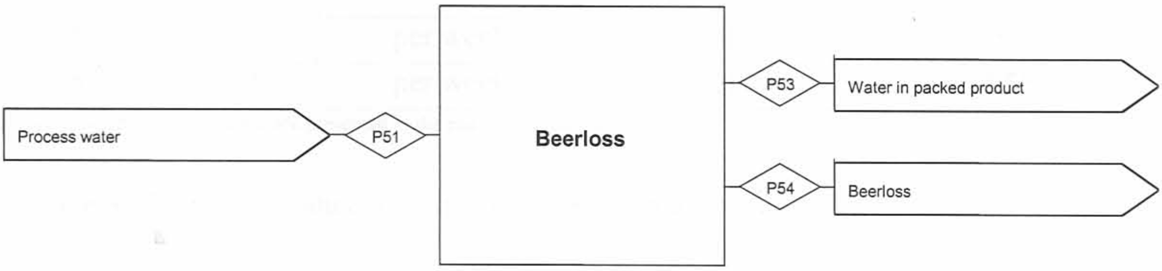
Figure 5.15 Water balance over the pasteuriser (can line).

Shrinkwrapper, traypacker and palletiser

The shrinkwrapper, traypacker and palletiser are washed by an operator, on average, for one hour per week. The volumes of water used to clean these machines are of an order of magnitude less than what is used by the other equipment on the line and the volumes will therefore be ignored (Van der Merwe, 2000). (Since plastic belts are used to transport the cans between equipment, chain lube is not used on a can line.)

Beerloss

The water balance associated with the beer lost to the drains on the can line is shown in Figure 5.16. During the packing process, beerlosses are inevitable and these losses are discharged to the drains. It is expected that, on average, 1,25% of the beer packed is lost to the drains (Davis, 2000). Therefore, if the line packs on average 15 839 hl of beer per week, 198 hl of beer is lost to the drains per week.



Stream	Volume [hl]	Frequency	Ave volume/week [hl/week]	Source ⊕
P51	15 839	per week	15 839	Section 4.3
P53	15 641	per week	15 641	P51– P54
P54	198	per week	198	S13

⊕ Sources, other than streams, are presented at the end of each chapter.

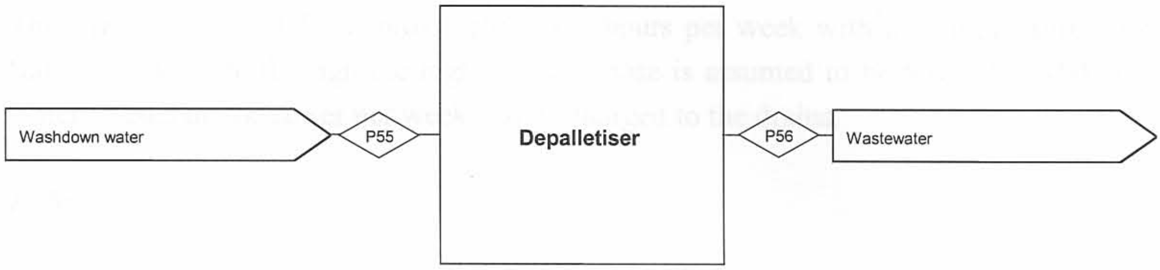
Figure 5.16 Water balance associated with beer lost to the drains (can line).

5.2.3 Water use on the nonreturnable bottle line

The nonreturnable bottle line is rated to pack 170 hl/h of beer into 340 ml bottles. The line packs on average 2 010 hl/day at an average line efficiency of 80% (SAB, 2001). Therefore the line is in operation, on average 15 hours per day.

Depalletiser

The water balance over the depalletiser is shown in Figure 5.17. The depalletiser is washed daily with high-pressure hoses for approximately one hour and undergoes a thorough clean on a weekly basis for approximately two hours. Since the average flowrate through a high pressure hose is assumed to be 5 000 l/h, 350 hl of water is used per week and discharged to the drains (SAB, 2001).



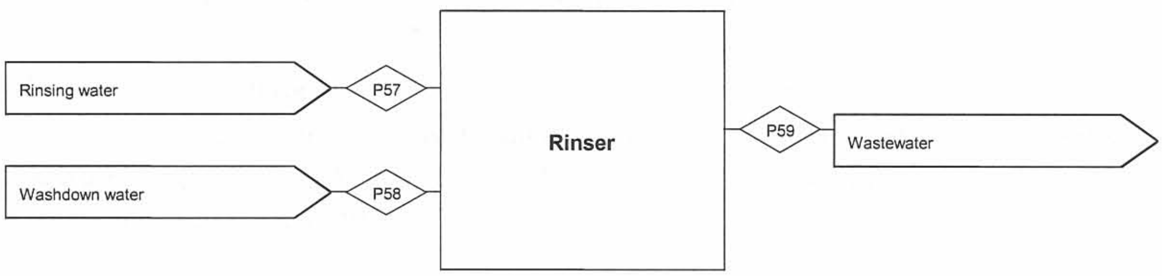
Stream	Volume [hl]	Frequency	Ave volume/week [hl/week]	Source ⊕
P55	350	per week	350	S4
P56	350	per week	350	P55

⊕ Sources, other than streams, are presented at the end of each chapter.

Figure 5.17 Water balance over the depalletiser (handy line).

Rinser

The water balance over the rinser is shown in Figure 5.18. The rinser sprays water into the bottles at a rate of 35 hl per hour (Myoli, 2000) and this water is discharged to the drains. Assuming the line is active for 15 hours per day, the volume of water used to rinse the bottles per week, is 2 625 hl.



Stream	Volume [hl]	Frequency	Ave volume/week [hl/week]	Source ⊕
P57	2 625	per week	2 625	S14
P58	250	per week	250	S4
P59	2 875	per week	2 875	P57+ P58

⊕ Sources, other than streams, are presented at the end of each chapter.

Figure 5.18 Water balance over the rinser (handy line).

The rinser is washed for approximately five hours per week with a high-pressure hose. Since the flowrate through the high-pressure hose is assumed to be 5 000 l/h, 250 hl of water is used on the rinser per week and discharged to the drains.

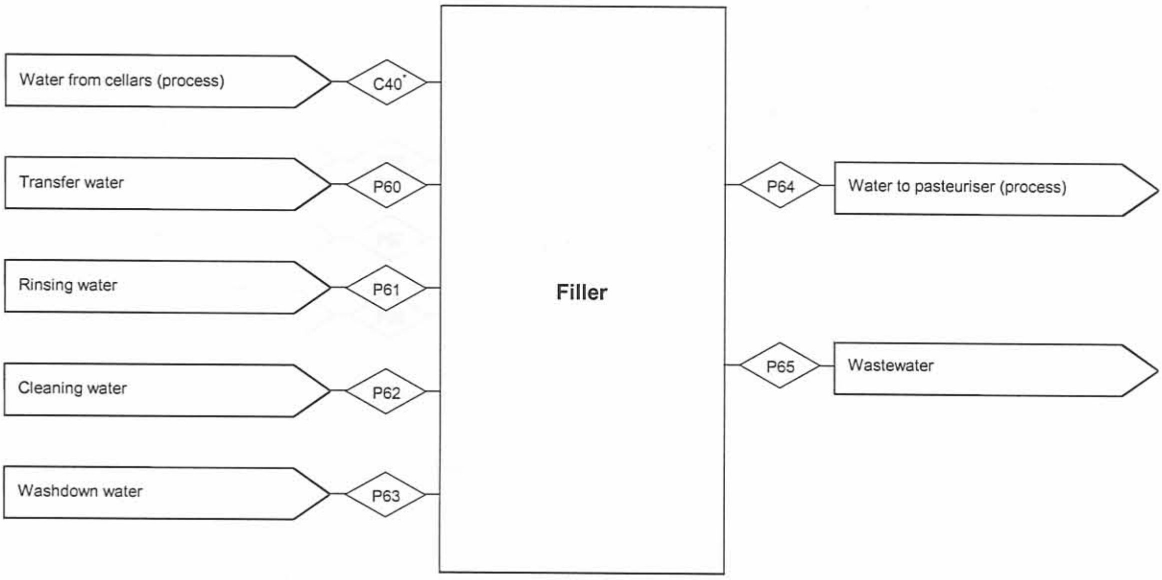
Filler

The water balance over the nonreturnable bottle line filler is shown in Figure 5.19. 10 050 hl of beer per week (2 010 hl/day) is transferred to the filler on the nonreturnable bottle line. Before the transfer of beer from the BBT's to the filler, deaerated water is used to displace air in the filler lines at a rate of 170 hl/h for 10 minutes. This practice occurs, on average, once a day and the resultant 142 hl per week of deaerated water is discharged to the drains. On completion of the beer transfer, deaerated water is used to transfer any beer remaining in the lines to the filler at the same rate and periods as above. In total, 284 hl of water per week is used in the transfer of beer to the filler and discharged to the drains.

As with the quart line, after the bottle has been filled, jetting occurs. However, the volume of water used for jetting is of an order of magnitude lower than the volumes generated from the other unit processes and is assumed negligible (Van der Merwe, 2000). After the bottles have been filled and crowned, they are rinsed at an average rate of 10 hl/h, as established by the plant trials of November 2000 (Van der Merwe, 2000). Therefore, the average volume of water used per week to rinse the cans is 750 hl.

The beer lines undergo a CIP once every second week at a rate of 231 hl/h. The CIP cycle continues for approximately 40 minutes, of which 15 minutes of flow is expected to discharge to the drains (Myoli, 2000). Therefore the average volume of water used to CIP the lines per week is 29 hl.

The filler is washed on average once a week with high pressure hoses for approximately 4 hours. If it is assumed that the average throughput of a high-pressure hose is 5 000 l/h, then the average volume of water used to clean the line is 200 hl/week.



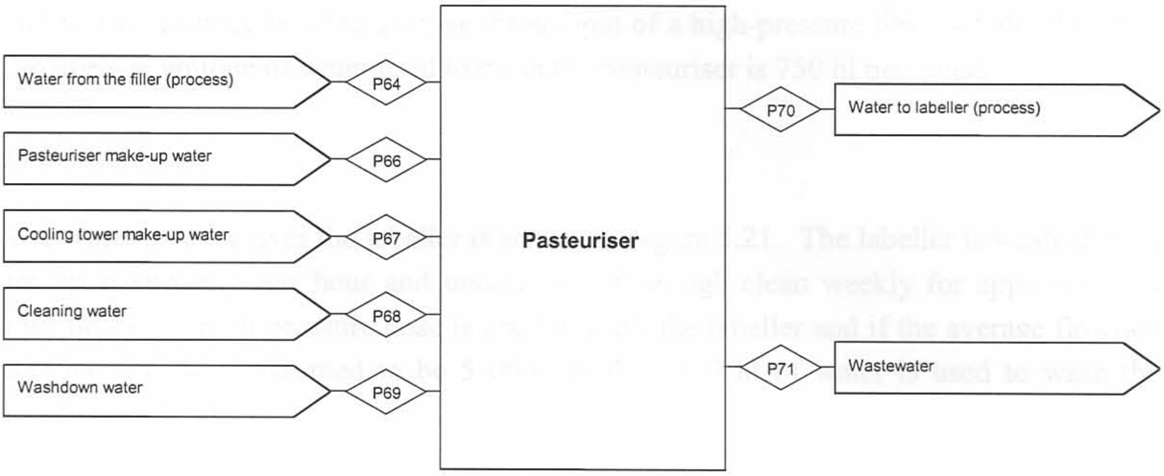
Stream	Volume [hl]	Frequency	Ave volume/week [hl/week]	Source ⊕
C40*	10 050	per week	10 050	Section 4.3
P60	284	per week	284	S4
P61	750	per week	750	S14
P62	29	per week	29	S14
P63	200	per week	200	S4
P64	10 050	per week	10 050	C39
P65	1 263	per week	1 263	P60+ P61+ P62+ P63

⊕ Sources, other than streams, are presented at the end of each chapter. * part of C40.

Figure 5.19 Water balance over the filler (handy line).

Pasteuriser

The water balance over the pasteuriser on the nonreturnable bottle line is shown in Figure 5.20. Water is added at a rate of 40 hl per hour to compensate for the carry over of water by the bottles (Schumacher, 2000) and the resultant 3000 hl/week discharged to the drains. Spray bars are cleaned once a year for 10 minutes with the assistance of high-pressure hoses. This volume of water is assumed to be negligible.



Stream	Volume [hl]	Frequency	Ave volume/week [hl/week]	Source ⊕
P64	10 050	per week	10 050	Section 4.3
P66	3 000	per week	3 000	S12
P67	1 800	per week	1 800	S9
P68	240	per week	240	S9
P69	750	per week	750	S4
P70	10 050	per week	10 050	P64
P71	5 790	per week	5 790	P66+ P67+ P68 + P69

⊕ Sources, other than streams, are presented at the end of each chapter.

Figure 5.20 Water balance over the pasteuriser (handy line).

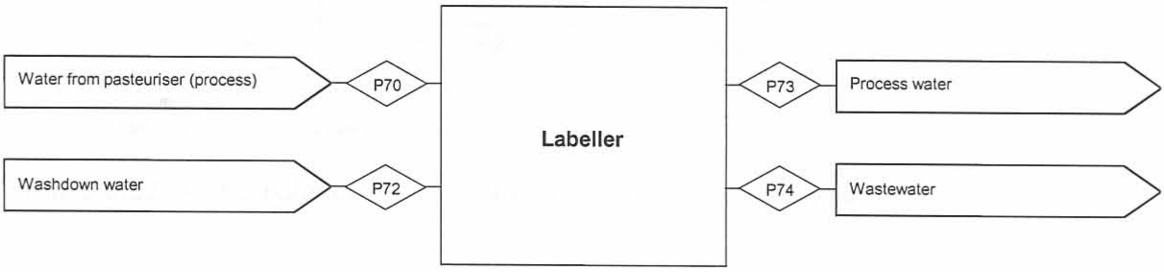
Water supplied to the final compartment of the pasteuriser is circulated between the cooling towers and the pasteuriser. On average, a flow of 24 hl/h is expected to make-up for losses incurred (SAB, 2001). Therefore, assuming that the line is in operation for 15 hours per day, the average volume of water required to make-up the volumes in the cooling towers is 1 800 hl per week.

When the quality of the water within the pasteuriser compartments deteriorates below a certain level, it is discharged to the drains. The average volume of cleaning water added per week is 240 hl (SAB, 2001).

The pasteuriser is washed daily for two hours and undergoes a thorough clean once a week for an average of five hours. High-pressure hoses are used to clean the pasteuriser and if it is assumed that the average throughput of a high-pressure hose is 5 000 l/h, then the average volume of water used to clean the pasteuriser is 750 hl per week.

Labeller

The water balance over the labeller is shown in Figure 5.21. The labeller is washed daily for approximately one hour and undergoes a thorough clean weekly for approximately four hours. A high-pressure hose is used to wash the labeller and if the average flowrate through a hose is assumed to be 5 000 l/h, then 450 hl of water is used to wash the labeller per week.



Stream	Volume [hl]	Frequency	Ave volume/week [hl/week]	Source ⊕
P70	10 050	per week	10 050	Section 4.3
P72	450	per week	450	S4
P73	10 050	per week	10 050	P70
P74	450	per week	450	P72

⊕ Sources, other than streams, are presented at the end of each chapter.

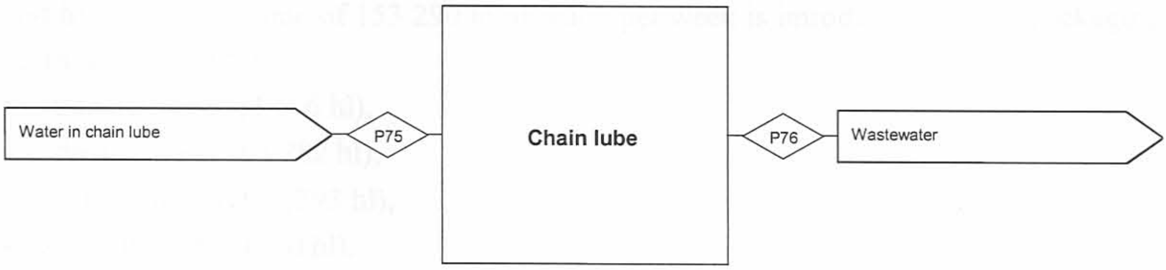
Figure 5.21 Water balance over the labeller (handy line).

Shrinkwrapper, traypacker and palletiser

The shrinkwrapper, traypacker and palletiser are washed for one hour per week on average. The volumes of water used to wash these machines are of an order of magnitude lower than the volumes generated from the other unit processes and is therefore assumed to be negligible (Van der Merwe, 2000).

Chain lube

The water balance associated with chain lube on the nonreturnable bottle line is shown in Figure 5.22. To reduce friction between the moving parts of the conveyor and between the conveyor and the bottles, a chain lube mixture is added. The volume of water used for lubrication is 704 hl, based on 7 litre of water per hl of beer packed (see Section 5.1.1).



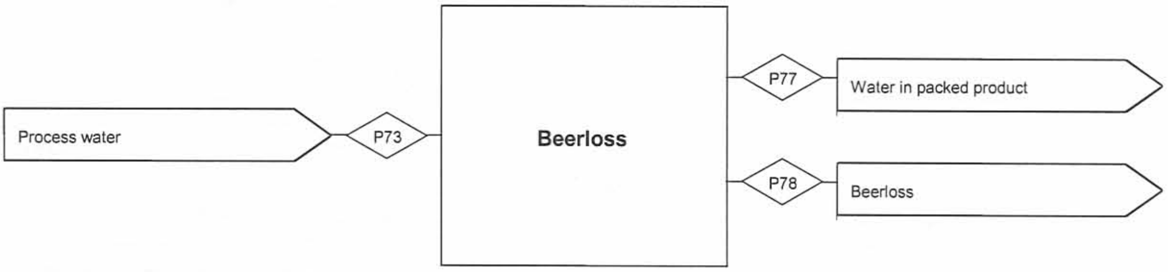
Stream	Volume [hl]	Frequency	Ave volume/week [hl/week]	Source ⊕
P75	704	per week	704	S13
P76	704	per week	704	P75

⊕ Sources, other than streams, are presented at the end of each chapter.

Figure 5.22 Water balance associated with chain lube (handy line).

Beerloss

The water balance associated with the beer lost to the drains is shown in Figure 5.23. During the packing process, beerlosses are inevitable and these losses are discharged to the drains. It is expected that, on average, 1,25% of the beer packed is lost to the drains (Davis, 2000). Therefore, if the line packs, on average, 10 050 hl of beer per week, 126 hl of beer is lost to the drain per week.



Stream	Volume [hl]	Frequency	Ave volume/week [hl/week]	Source ⊕
P73	10 050	per week	10 050	Section 4.3
P77	9 924	per week	9 924	P73 – P78
P78	126	per week	126	S13

⊕ Sources, other than streams, are presented at the end of each chapter.

Figure 5.23 Water balance associated with beer lost to the drains (handy line).

5.3 OVERALL WATER BALANCE IN PACKAGING

The overall water balance over the entire packaging section is shown in Figure 5.24 (a and b). A total volume of 153 290 hl of water per week is introduced into the packaging section and used for

- transfer water (4 666 hl),
- rinsing water (68 782 hl),
- cullet flush water (393 hl),
- vacuum pump (930 hl),
- pasteuriser make-up water (29 675 hl),
- cooling tower make-up water (8 640 hl),
- water within chain lube (5 897 hl),
- cleaning water (19 432 hl), and
- washdown water (14 875 hl).

Since 98 813 hl of beer is packed into the required containers, the water ratio can be calculated as

$$\text{Water ratio for the packaging section} = \frac{153290}{98813} = 1{,}55$$

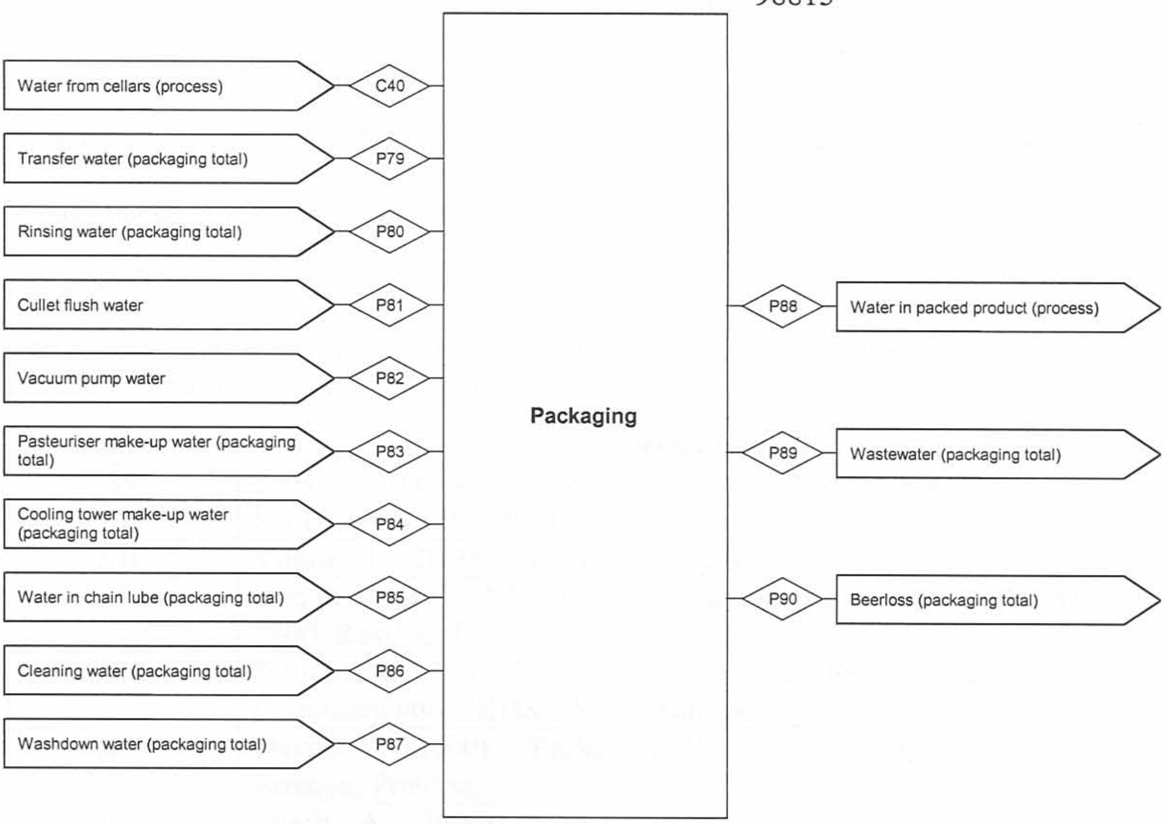


Figure 5.24a The overall water balance for the packaging section at the Rosslyn plant.

Stream	Volume per week (hl/week)	Source
C40	100 064	Section 4.3
P79	4 666	3 x P13 + P42 + P60
P80	68 782	3 x P6 +3 x P10 +3 x P14 + P39 + P43 + P57 + P61
P81	393	3 x P15
P82	930	3 x P16
P83	29 675	3 x P21 + P48 + P66
P84	8 640	3 x P22 + P67
P85	5 897	3 x P33 + P75
P86	19 432	3 x P3 +3 x P7 +3 x P17 + 3 x P23 + P44 + P49 + P62 + P68
P87	14 875	3 x P1 +3 x P4 +3 x P8 + 3 x P11 + 3 x P18 + 3 x P24 + 3 x P27 + 3 x P30 + P37 + P40 + P45 + P50 + P55 + P58 + P63 + P69 + P72
P88	98 813	3 x P35 + P53 + P77
P89	153 290	3 x P2 + 3 x P5 + 3 x P9 + 3 x P12 + 3 x P20 + 3 x P26 + 3 x P29 + 3 x P32 + 3 x P34 + P38 + P41 + P47 + P52 + P56 + P59 + P65 + P71 + P74+ P76
P90	1 251	3 x P36 + P54 + P78

Figure 5.24b The overall water balance for the entire packaging section.

5.4 SOURCES

The sources used within this chapter for calculating the different water balances over the packaging section are presented below.

Source	Reference
S9	SAB, (2001), Activity Reports for the Rosslyn Packaging Section, SA Breweries Rosslyn plant, Pretoria.
S10	Volmer, P. (2000) Washer Cleaning Schedules, Rosslyn, Pretoria.
S11	Van der Merwe, A.I. (2000) Plant trials conducted during November 2000, Rosslyn, Pretoria.
S12	Schumacher, P. (2000), "Water Use at the Rosslyn Plant", Personal Communication, KHS – SA, Johannesburg.
S13	Davis, T. (2000), "Packaging Water", Personal Communication, Rosslyn, Pretoria.
S14	Myoli, A. (2000), "Packaging Water", Personal Communication, Rosslyn, Pretoria.

CHAPTER 6

OVERALL WATER BALANCE

6.1 INTRODUCTION

The overall water balance at the Rosslyn plant (see Figure 6.1) includes water used by the brewhouse (Chapter 3), the cellars (Chapter 4), packaging (Chapter 5) and general users (Section 6.2). Stormwater will not be considered as part of the overall water balance as there are no uncovered holding facilities at the plant. All rain water falling onto the plant, and surrounding areas within the plant's boundary fences, is diverted to stormwater conduits and discharged to the sewers.

6.2 GENERAL WATER USE

At the Rosslyn plant, additional water production/treatment facilities are present to supply the plant with, *inter alia,* steam, high temperature water, cold water, cleaning water and drying water. The utilities department is responsible for the management of these facilities, which are represented as general water in Figure 6.1. As shown in Figure 6.2, general water is utilised within three main areas, namely:

- boilerhouse – supplying high temperature water and steam for various purposes,
- site – supplying water for toilet facilities, canteen requirements, etc, and
- engine room – supplying water for the cleaning and cooling of gases.

6.2.1 Boilerhouse

The boilerhouse supplies high temperature water and steam to unit processes on the brewery site. High temperature water is distributed as a heating medium to, *inter alia*, the mash tun and the wort kettle. This water is circulated back to the boilerhouse and reheated to the required temperature for reuse. Water losses are inevitable and the water levels are made up with potable water.

The boilerhouse also supplies steam to the yeast drying plant, the deodorisers and the activated carbon filters. The steam supplied to the yeast drying plant is used to dry the scrap yeast (before it is bagged) and escapes to the atmosphere after contact with the wet yeast. At the deodorisers and activated carbon filters the steam is utilised for regeneration purposes before release to the atmosphere.

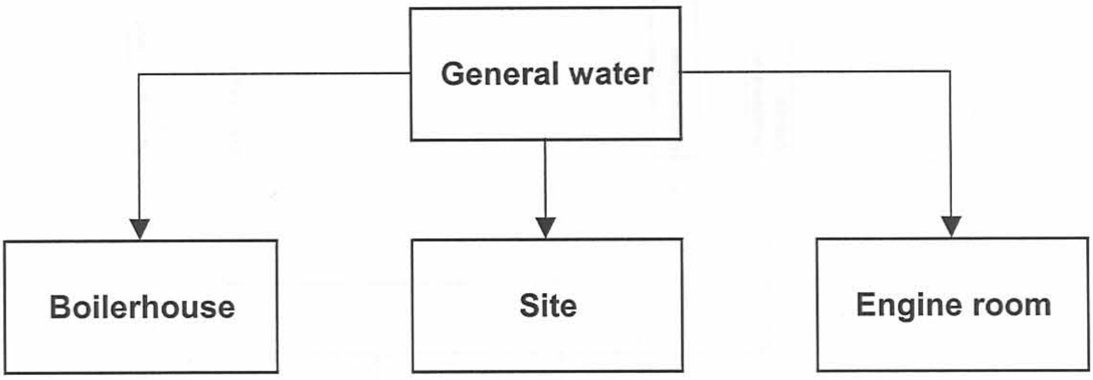
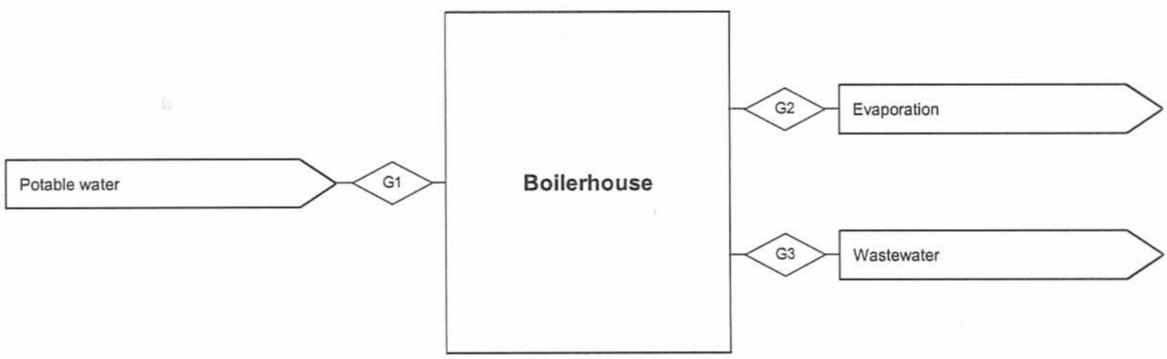


Figure 6.2 Breakdown of the water used for general purposes.



Stream	Volume per week (hl/week)	Source ⊕
G1	9 877	S15
G2	7 408	S3
G3	2 469	G1 – G2

⊕ Sources, other than streams, are presented at the end of each chapter.

Figure 6.3 Water balance over the boilerhouse.

The Rosslyn plant measures the total water utilised by the boilerhouse which equates to approximately 9 877 hl of water per week (Kristin, 2000). It is estimated that 75% of this water (7 408 hl per week) is evaporated to the atmosphere with the remainder incurred as losses to the drains (Van der Merwe, 2000). The water balance over the boilerhouse is shown in Figure 6.3.

6.2.2 Site water

Site water is utilised by Rosslyn personnel for general purposes, in the brewhouse, the cellars and the packaging hall. The water balance for site water is shown in Figure 6.4.

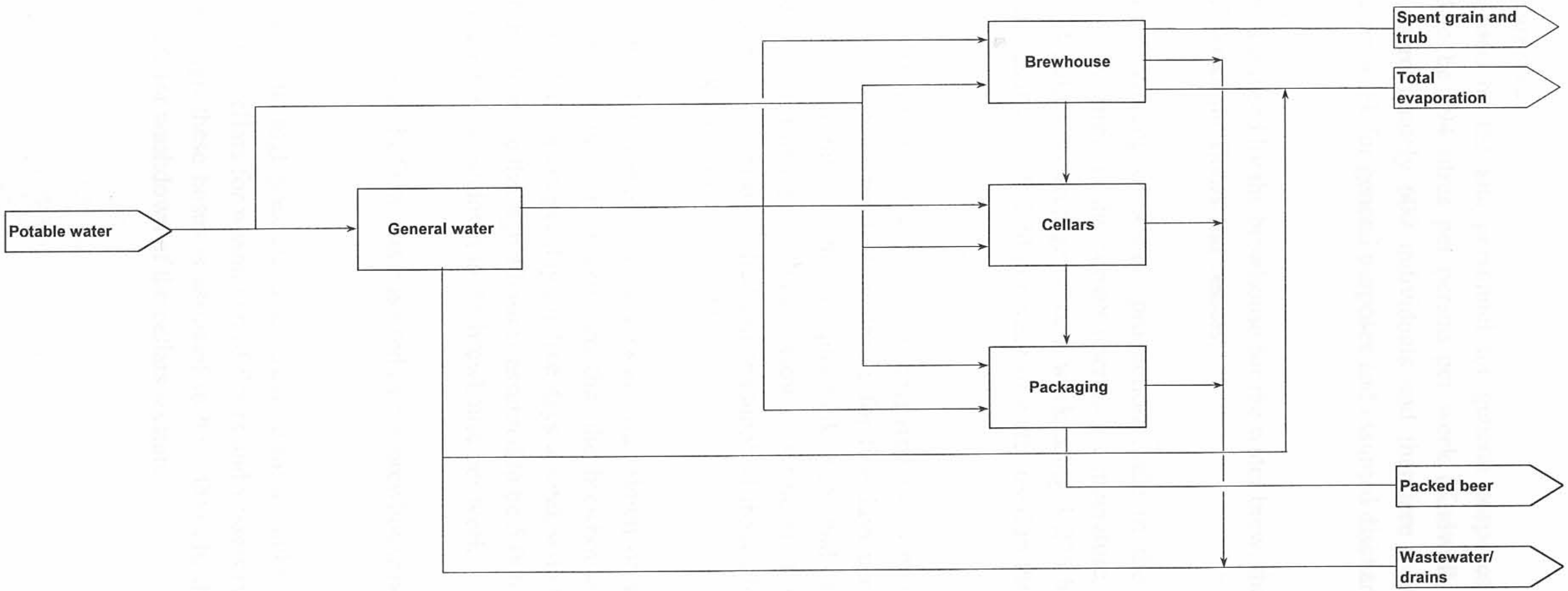


Figure 6.1 Flow diagram of the overall water balance at the Rosslyn plant.

General purposes

Water is used by the site personnel for general purposes and the volumes used are estimated to be 494 litres per person per week (Kadwell, 2001). The Rosslyn plant employs approximately 600 individuals and therefore 2 964 hl of water is used by personnel per week for general purposes and assumed discharged to the drains.

Brewhouse

Site water is utilised by the brewhouse for the water brew, the chilled liquor tanks and for the washdown of the floors and vessels.

Before the beginning of a new production cycle in the brewhouse, the brewhouse prepares a water brew to the correct operating temperature. It is estimated that a water brew is undertaken on average twice a week using 3 276 hl of water per brew (Isaacs, 2001). The resultant 6 552 hl per week of water used in the brewhouse is discharged to the drains.

At the Rosslyn plant, chilled liquor is prepared for wort cooling during a production cycle. However, since production occurs for five days per week, there may be chilled liquor remaining within the chilled liquor tank at the end of a production cycle. Should the temperature of this liquor deviate below its set point, it is discharged to the drains. It is estimated that 400 hl of chilled liquor (supplied from site water) is discharged to the drains on a weekly basis (Rex, 2001).

To ensure that the brewery remains clean, washdown of vessels and floors with high pressure hoses occurs. It is assumed that the brewhouse is washed for a combined average total of 15 hours per day for five days a week with these hoses (van der Merwe, 2000). If the flowrate through a hose is assumed to be 5 000 l/h on average, then 3 750 hl of water is used for washdown in the brewhouse per week.

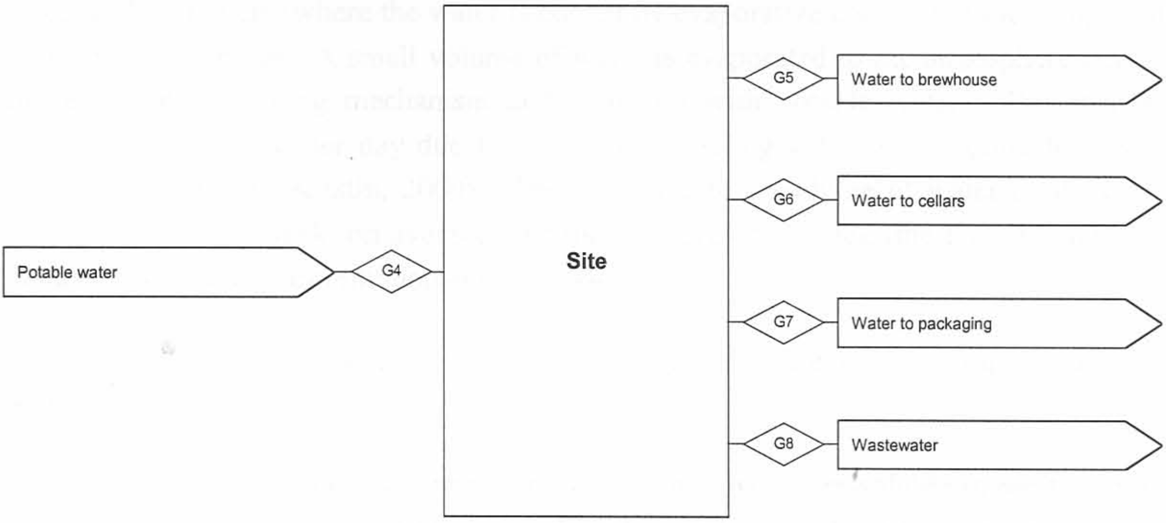
Therefore, 10 702 hl of site water is used by the brewhouse per week.

Cellars

It is estimated that high pressure hoses are used for a combined average total of 125 hours per week in the cellars for washdown of floors and vessels (van der Merwe, 2000). If the flowrate through these hoses is assumed to be 5 000 l/h, then 6 250 hl of site water is used per week for washdown of the cellars section.

Packaging

In the packaging hall site water is also used for washdown purposes. It is estimated that high pressure hoses are used for a combined average total of 21 hours per day (five days per week) for each of the five production lines (Myoli, 2001). If the flowrate through these hoses is assumed to be 5 000 l/h, then 26 250 hl of site water is used per week for washdown of the packaging hall.



Stream	Volume per week (hl/week)	Source ⊕
G4	46 166	G5 + G6 + G7 + G8
G5	10 702	S3, S5
G6	6 250	S3
G7	26 250	S14
G8	2 964	S16

⊕ Sources, other than streams, are presented at the end of each chapter.

Figure 6.4 Water balance for site water.

6.2.3 Engine room

The water balance over the engine room is shown in Figure 6.5. The engine room supplies water to the ammonia condensers, the closed circuit water cooling (CCWC) cycle, scrubbers and the foam traps.

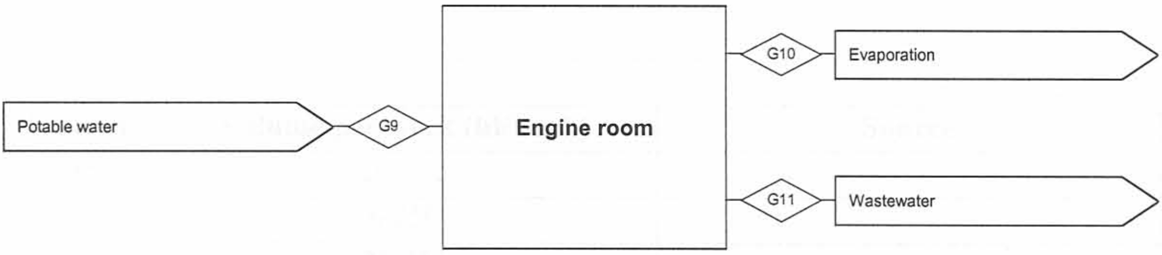
Ammonia, used as a coolant throughout the brewery site, is cooled with water supplied by the engine room. The Rosslyn plant is equipped with two sets of six ammonia condensers. The average volume of water used per day, for seven days per week (the fermentation and storage vessels operate continuously), by both sets of ammonia condensers for evaporative cooling (which is lost to the atmosphere) is 4 332 hl (Kristin, 2000). Therefore, the total volume of water used per week, on average, by the ammonia condensers is 30 324 hl.

The engine room also supplies water to the closed circuit water cooling (CCWC) cycle which is used to cool, *inter alia,* the carbon dioxide compressors, air compressors and the mechanical seals on certain pumps. Water in the CCWC circuit is transferred through three cooling towers (where the water is cooled by evaporative cooling) to the equipment requiring the cooling. A small volume of water is evaporated to the atmosphere during the evaporative cooling mechanism and made up with potable water. The average volume of water lost per day due to evaporative cooling within the cooling towers is estimated at 392 hl (Kristin, 2000). Therefore, the total volume of water used by the CCWC circuit per week, on average, assuming a seven day week (the fermentation and storage vessels operate continuously), is 2 744 hl.

Therefore, 33 068 hl of water per week, supplied by the engine room, is evaporated to the atmosphere.

At the Rosslyn plant, three scrubbers are used to remove water-soluble impurities from CO_2. During contact of the CO_2 gas with water spray droplets in the scrubbers, water soluble impurities are dissolved in the water. Potable water is purged on a continuous basis to the scrubbers to prevent the build-up of contaminants. The internal surfaces of the scrubbers also require regular CIP cleaning to remove contaminants. Assuming that the three scrubbers are in operation (not necessarily operating at the same time) for seven days per week, the fermentation and storage vessels operate continuously, the total volume of water used per day, for make-up and CIP cleaning, is 1 891 hl (Kristin, 2000).

Therefore the volume of water used by the scrubbers per week is 13 237 hl.



Stream	Volume per week (hl/week)	Source
G9	48 370	G10 + G11
G10	33 068	S15
G11	15 302	S15

⊕ Sources, other than streams, are presented at the end of each chapter.

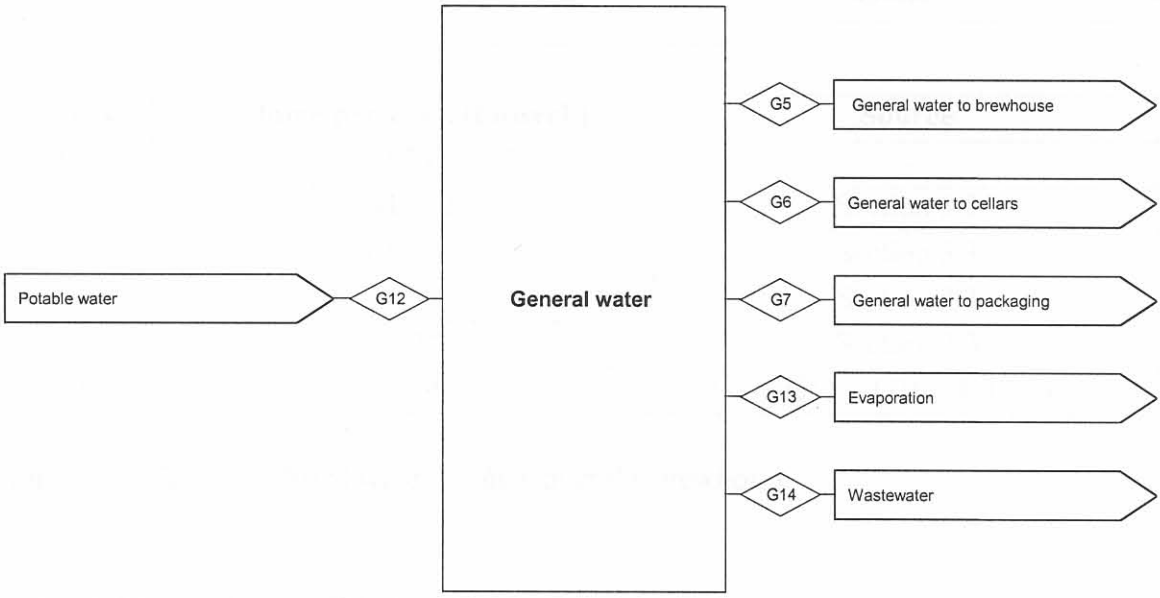
Figure 6.5 Water balance over the engine room.

The foam traps are fitted with water spray nozzles and screens to remove fob (beer foam) from the CO_2. For the continuous removal of fob, the traps have a continuous potable water supply to ensure that a constant level of water is maintained inside the foam traps, with excess water overflowing to the drains. The foam traps also undergo a regular CIP clean. The average volume of water used by the foam traps per day is 295 hl (Kristin, 2000).

Therefore, 15 302 hl of water is supplied by the engine room per week and is discharged to the drains.

6.2.4 Water balance for general water

The water balance for the general water used in the brewery is shown in Figure 6.6. 104 413 hl of water is used for general purposes by the boilerhouse, site and engine room.

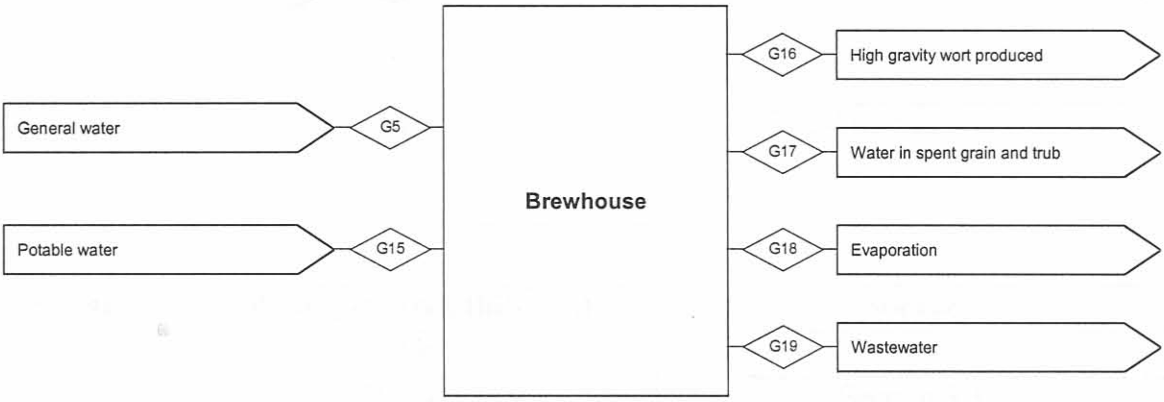


Stream	Volume per week (hl/week)	Source
G5	10 702	-
G6	6 250	-
G7	26 250	-
G12	104 413	G5 + G6 + G7 + G13 + G14
G13	40 476	G2 + G10
G14	20 735	G3 + G8 + G11

Figure 6.6 Water balance for general water.

6.3 BREWHOUSE WATER BALANCE

A simplified water balance over the brewhouse (from Chapter 3 and incorporating general water use) is shown in Figure 6.7. 151 874 hl of water is used per week by the brewhouse in the production of 70 560 hl of high gravity wort.

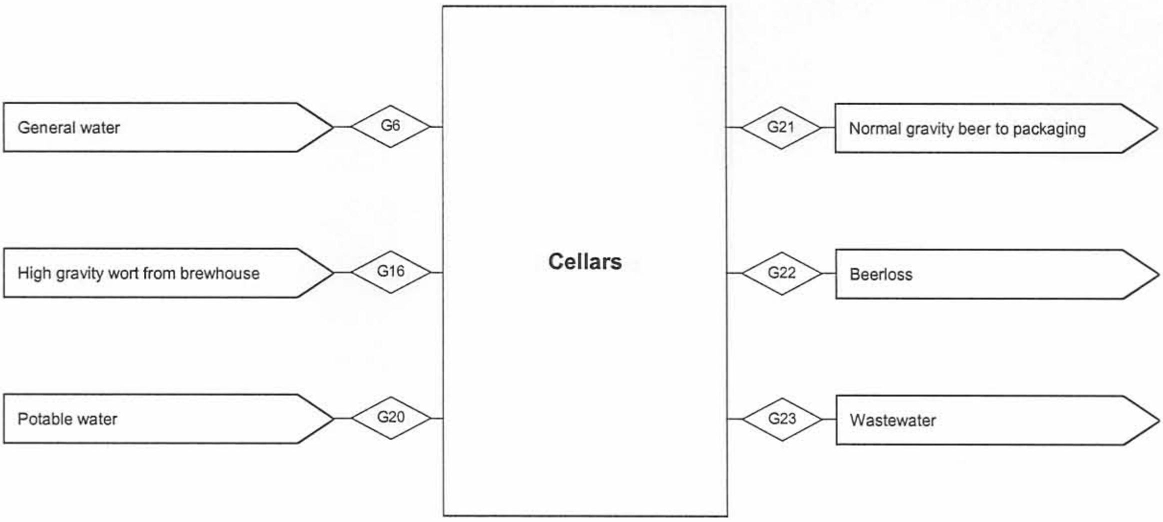


Stream	Volume per week (hl/week)	Source
G5	10 702	-
G15	141 172	Section 3.3
G16	70 560	Section 3.3
G17	3 200	Section 3.3
G18	5 024	Section 3.3
G19	73 090	G5 + G15 – G16 – G17 – G18

Figure 6.7 The simplified water balance over the brewhouse.

6.4 CELLARS WATER BALANCE

A simplified water balance over the cellars (from Chapter 4 and incorporating general water use) is shown in Figure 6.8. 99 098 hl of water per week is introduced into the cellars section to produce 100 064 hl of normal gravity beer.

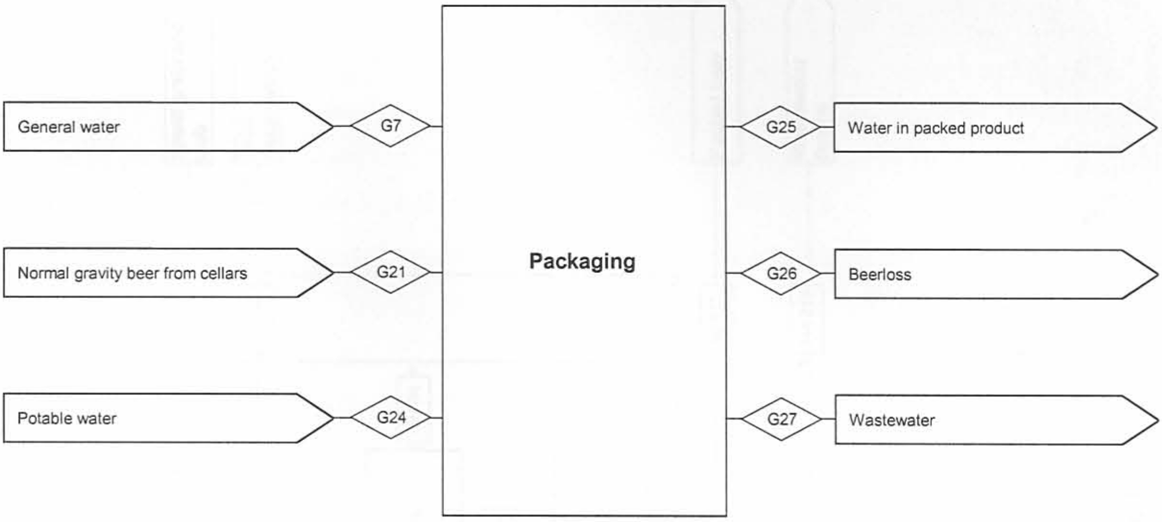


Stream	Volume per week (hl/week)	Source
G6	6 250	-
G16	70 560	Section 3.3
G20	92 848	Section 4.3
G21	100 064	Section 4.3
G22	3 168	Section 4.3
G23	66 426	G6 + G16 + G20 – G21 – G22

Figure 6.8 The simplified water balance over the cellars.

6.5 PACKAGING WATER BALANCE

A simplified water balance over the packaging section (from Chapter 5 and incorporating general water use) is shown in Figure 6.9. 179 540 hl of water per week is introduced into the packaging section for the production of 98 813 hl normal gravity beer.



Stream	Volume per week (hl/week)	Source
G7	26 250	-
G21	100 064	Section 4.3
G24	153 290	Section 5.3
G25	98 813	Section 5.3
G26	1 251	Section 5.3
G27	179 540	G6 + G17 + G25 + G28 – G29 – G30

Figure 6.9 The simplified water balance over the packaging hall.

6.6 OVERALL WATER BALANCE

The overall water balance at the Rosslyn brewery is shown in Figure 6.10. 491 723 hl of water is utilised to produce 98 813 hl of pack
ed beer product per week, resulting in

Ratio of water utilised : beer produced = 491 723/98 813 = 4,98 (hl/hl)

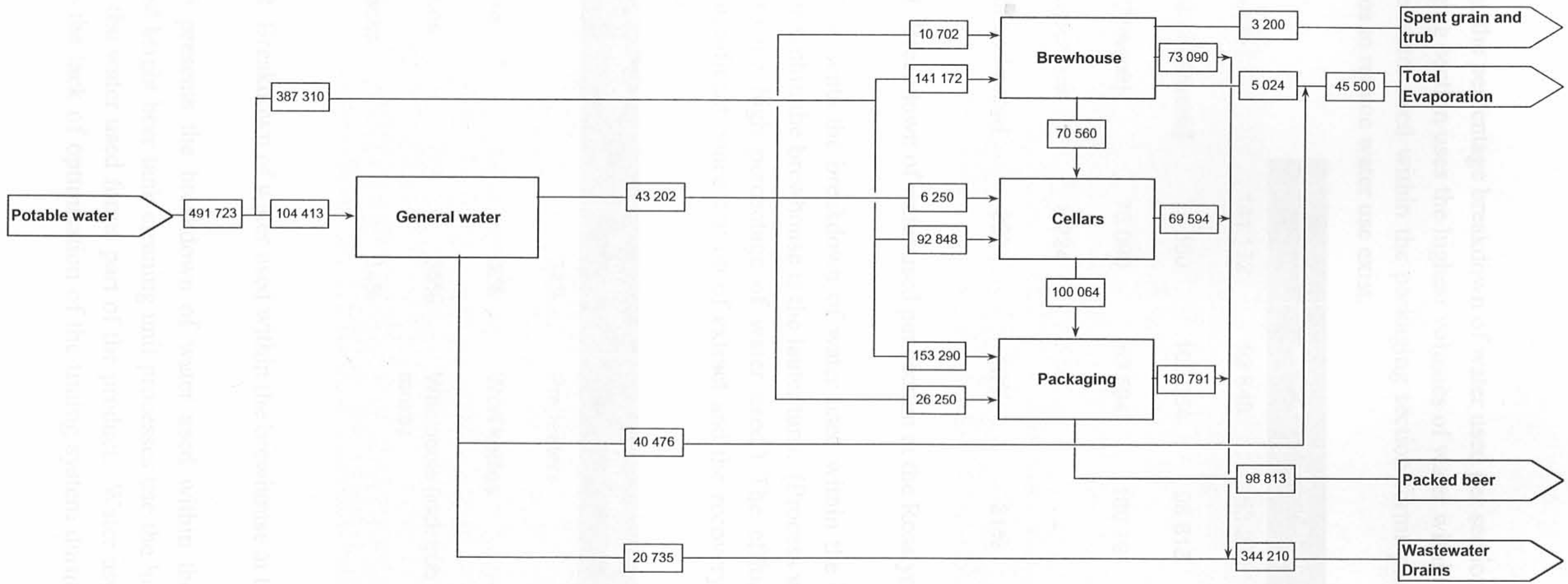


Figure 6.10 The flow diagram of the overall water balance at the Rosslyn plant (flows in hl/week).

In summary, the percentage breakdown of water used per section is shown in Figure 6.11. The packaging section uses the highest volumes of water within the Rosslyn plant. Since none of the water used within the packaging section forms part of the product, various opportunities to reduce water use exist.

	Brewhouse	Cellars	Packaging	General	Total
Water in [hl/week]	141 172	92 848	153 290	104 413	491 723
Water in product [hl/week]	70 560	100 064	98 813	-	98 813
Wastewater [hl/week]	73 090	69 594	180 791	20 735	344 210
Other and evaporation	8 224	-	-	40 476	48 700
Percentage of total water]	29%	19%	31%	21%	

Figure 6.11 Breakdown of water used per section at the Rosslyn plant.

Figure 6.12 presents the breakdown of water used within the brewhouse. The highest user of water within the brewhouse is the lauter tuns. (Process water is added to the mills attributing to the high percentage of water used.) The effluent from the lauter tuns contains a significant concentration of extract and the recovery of this liquor should be investigated.

Unit process	% of total	Unit process	% of total
Mills	34%	Preheaters	3%
Mash tuns	2%	Wort kettles	3%
Lauter tuns	35%	Whirlpools (incl. trub tanks)	9%
Underbacks	14%		

Figure 6.12 Breakdown of water used within the brewhouse at the Rosslyn plant.

Figure 6.13 presents the breakdown of water used within the cellars. Although the blending and bright beer tank cleaning unit processes use the highest water volumes, the majority of the water used forms part of the product. Water used within wort cooling is high due to the lack of optimisation of the timing system during the transfer of product from the whirlpools to the fermentation vessels. Management of this process may significantly reduce the volumes used.

Unit process	% of total	Unit process	% of total
Wort cooling	21%	Maturation	8%
Yeast pitching	7%	Filtration	11%
Fermentation	11%	Blending & bright beer tank cleaning	41%
Racking	0%		

Figure 6.13 Breakdown of water used within the cellars section at the Rosslyn plant.

Water used in the packaging section and by general users do not form part of the product and possible opportunities to reduce the volumes consumed need to be investigated.

6.7 COST OPPORTUNTIES RELATED TO WATER MINIMISATION

Initiatives to minimise water used by the brewery will result in a reduction in both influent and effluent water costs. The brewery is charged 2c/kl of potable water by the Tshwane Metro local council. Effluent charges are based on the following formula :

$$\text{Rand} = \text{Volume [kl] x} \left(0{,}64 + \frac{0{,}66 \times COD}{1000}\right), \text{ with COD in mg/l.}$$

With the current effluent volumes of 34 410 kl and an average chemical oxygen demand (COD) content of 3 500 mg/l, the Rosslyn plant is paying R 5,5 million in effluent costs. If it is assumed that the pecentage reduction in effluent volumes will subsequently result in the same percentage increase in COD concentration, then the water savings which can be attained by minimising water entering the plant is shown in Figure 6.14. From the graph it is clear that the brewery should be aiming to reduce water usage to the lowest levels possible, as the influence of this reduction, and the subsequent increase in COD concentration, continuously result in a reduction in the effluent costs.

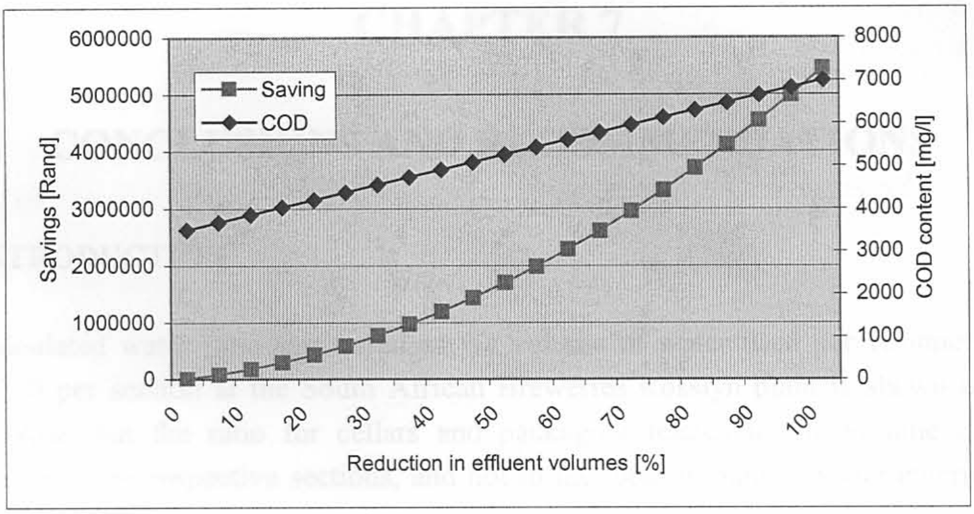


Figure 6.14 Water savings associated with water minimisation at the Rosslyn plant.

6.8 SOURCES

The sources used within this chapter for calculating the overall water balance are presented below.

Source	Reference
S3	Van der Merwe, A.I. (2000) "Water Report for Brewhouse and Cellars" report to SAB Rosslyn plant, Pretoria.
S5	Isaacs, N. (2001) "Operation in the SAB Rosslyn Brewhouse", Personal Communication, Rosslyn Brewery, Pretoria.
S15	Kristin, J. (2000) "Water Utilisation in the Utilities Department at the Rosslyn Brewery", report to SAB Rosslyn plant, Pretoria.
S16	Kadwell, J. (2001) "Water Usage in Utilities", Personal Communication, Rosslyn Brewery, Pretoria.
S17	De Villiers, C. (2001) "Average Values for Stormwater and Evaporation over the Rosslyn Region", Personal Communication, Pretoria.
S18	Rex, J. (2001) "Water Usage within the brewhouse", Personal Communication, Rosslyn Brewery, Pretoria.

CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS

7.1 INTRODUCTION

The calculated water ratio (measured as the volume of water used per volume of beer produced) per section at the South African Breweries Rosslyn plant is shown in Table 7.1. (Note that the ratio for cellars and packaging relates to the volume of water introduced in the respective sections, and not to the total amount of water entering each section.)

Table 7.1 Summary of the calculated water ratios for each section at the Rosslyn plant.

Section	Water ratio (hl/hl)
Brewhouse	1,39
Cellars	0,93
Packaging	1,55
Overall (including general water)	4,98

The following sections address possible options to reduce the overall water usage at the plant.

7.2 CONCLUSIONS AND RECOMMENDATIONS OVER EACH SECTION AT THE ROSSLYN BREWERY

The minimisation of the water used within the brewery would ultimately result in lower effluent volumes and therefore lower effluent costs. However, since the effluent tariff is dependent on the volume and the chemical oxygen demand (COD) value, a reduction in effluent volumes could result in a more concentrated effluent. To reduce the effluent costs of the brewery to the greatest extent, the COD content of the effluent stream needs to be reduced in conjunction with the minimisation of the influent water volumes.

7.2.1 Brewhouse

Reuse of liquor from the lauter tun

A schematic representation of a portion of the brewhouse, with a recommended alteration to the system, is shown in Figure 7.1. The wastewater from the lauter tun (stream d) represents a large proportion of the water used in the brewhouse section. Once the cutoff volume to the underback (stream c) is reached, the liquor remaining in the lauter tun (stream d containing, *inter alia*, a small percentage of extractable sugars and unwanted elements), is discharged to the drains.

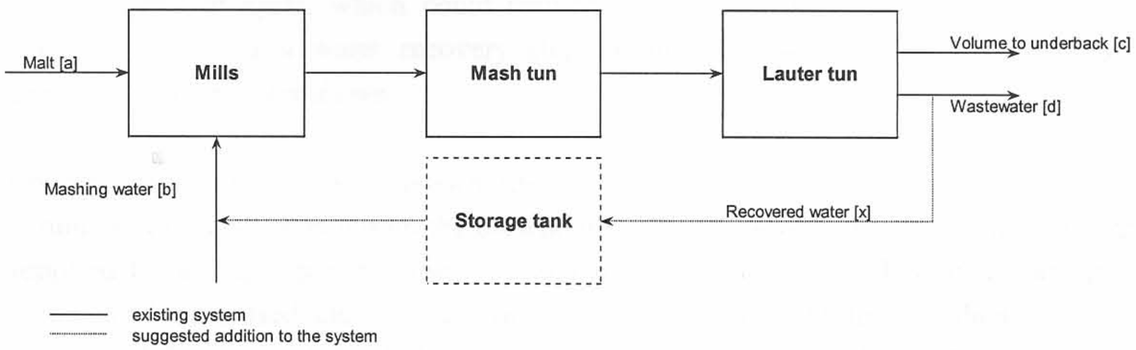


Figure 7.1 The existing system within the brewhouse at the Rosslyn plant and the recommended alteration to the system to recover liquor from the lauter tun.

The mass balance over the lauter tun in Chapter 3 reveals that approximately 39% of the process water entering the lauter tun is discharged to the drains as a part of stream d in Figure 7.1 (34 144 hl of process water per week is discharged to the drains of a total 87 424 hl of process water entering the lauter tun per week). Recovering a portion of this wastewater stream to the mills should be considered to reduce the amount of water required during milling and mashing. Laboratory tests should be conducted to determine the quality of this wastewater at different stages of the disposal to the drains, and its reuse capabilities as mash liquor in the following brew. These analyses may indicate the deterioration in the quality of the wastewater as a function of the time of disposal to the drains and a recoverable volume of water determined. This recovered water could be stored in a tank and transferred to the mash tun during milling of the next brew.

Rinse water

Approximately 29% of the wastewater from the brewhouse is due to the rinsing of vessels after the transfer of mash, mash liquor or wort to the following vessel. The solids concentration of the wastewater emanating from a rinse will decrease over time during the rinsing operation, that is, the quality of the water will improve. The water from the rinsing processes could be diverted to a separate storage vessel once the quality of the rinsing water is acceptable (for further use, to be determined from plant trials). This water could then be used as the first, or initial, rinse water of vessels during the next brewing cycle, resulting in a reduction in the volumes of water used for rinsing in the brewhouse. However, the cost associated with such a system, and the process viability of the recommendation, should be investigated.

Cleaning water

Approximately 21% of the wastewater from the brewhouse is due to the CIP cleaning of the vessels. The brewhouse at the Rosslyn plant does not have a water recovery system within their CIP cycle, which could result in substantial water savings. The process viability of adding a water recovery step to the CIP cycle should be investigated, similarly to rinse water above.

Control of the flowrates in the brewhouse

A number of the streams within the brewhouse at the Rosslyn plant are not measured and supplied by a single pump station, as explained in Chapter 3. This could affect the volumes of water used and also have quality implications on the final product. The areas of required flow control should be identified and flow meters installed. This will result in better control of the process and a better understanding of the water volumes used within the brewhouse.

Evaporation

5 024 hl of water is evaporated from the wort kettles with the steam containing small amounts of volatile compounds. Condensing the steam and removing volatile compounds through the use of, for example, activated carbon filters, the resultant water may be used for other purposes, like rinse and/or CIP water.

7.2.2 Cellars

Cooling water

240 hl of water per week is utilised for cooling the centrifuge during the racking process and is discharged directly to the drains. However, if this water is collected, it could be reused as cooling or cleaning water.

Water used during filtration

3 500 hl of water per week is used during backwashing of the filters. Prior to the transfer of beer to the filters, the filters are also precoated with filter aids and an average of 3 514 hl of water per week is used during this process and discharged to the drains. Depending

on the quality of the precoat water, it could be recovered and used as backwash water during the backwashing cycle.

Transfer water
Water utilised to transfer product between vessels forms approximately 16 % of the total water introduced into the cellars section. The transfer function is controlled in most cases by a timing system and optimisation of these times needs to be undertaken. Sections of plant where transfer water can be recovered and stored in separate vessels for reuse should be identified. Depending on the quality of recovered water, it may be utilised for other purposes, possibly washdown of the cellars section.

Cleaning water
The cellars section at the Rosslyn brewery has two CIP stations, each equipped with a water recovery system. These stations are capable of cleaning more than one vessel or pipeline system simultaneously. However, since each CIP station is equipped with only one vessel to store recovered water, recovery of the final rinse in a CIP cycle does not necessarily occur. (The CIP cycles of all the vessels and lines are not all the same and no schedule is in place when cleaning more than one vessel at the same time. The timing of the CIP programme needs to be investigated and optimised. Should the system and changeover between solutions be correctly optimised, substantial water savings within the cellars section are expected.

7.2.3 Packaging

Bottle washer rinsing water
59 850 hl of water is used, on average, by the three bottle washers per week. The bottle washer ultimately ensures that bottles returned from trade are cleaned before reuse. However, new bottles are also entered into the system and cleaned in the bottle washer, despite the fact that they are theoretically clean. The viability of either introducing these new bottles later on the line, or diverting them past the bottle washer (only to be rinsed before filling, as on the can and nonreturnable bottle lines) should be investigated. This will reduce the number of bottles being cleaned by the bottle washers, and the subsequent water used in the process.

In addition, the 59 850 hl of potable water used for rinsing is discharged to the drains. This water could rather be utilised in the crate washers where the quality of water used plays a lesser role, as the crates do not come into contact with the beer product.

Vacuum pump water

Similarly to the centrifuge cooling water in the cellars section, the 930 hl of water used per week by the vacuum pump is discharged to the drains and should rather be collected and reused, since very little deterioration in the water quality occurs.

After filling rinsing water

After the bottles are filled with beer they are rinsed with 4 062 hl of water (per week by the three lines) and this water discharged to the drains. However, this water could be reused for this rinsing cycle since the percentage of impurities in the water is normally not very high. The quality of this water should be checked regularly and once the quality deteriorates below a certain level, it can be discharged to the drains.

Can and nonreturnable bottle lines rinsing water

Before filling the cans and nonreturnable bottles with beer, they are rinsed with water which is discharged to the drains. 3 825 hl of water per week is used to rinse these containers. The quality of the discharged water is good and should either be recycled to the bottle or crate washers, or used as washdown water within the packaging hall.

Pasteuriser on the can line

The pasteuriser on the can line uses an average of 14 700 hl potable water in its final zone, which is discharged to the drains. As discussed in Chapter 5, this practice has been adopted to ensure that the cans are clean before packing into trays. However, the water used within the final zone should rather be recycled to the cooling towers and the cans rinsed with potable water on exiting the pasteuriser.

7.2.4 General water

Activated carbon filters

The effluent generated during backwashing and regeneration of the activated carbon filters is of sufficient quality to be used for other purposes in the brewery. These may include, *inter alia*, washdown of floors or equipment and toilet facilities.

Washdown water

The use of high pressure hoses should be managed and a culture change instilled to stop cleaners from unnecessarily using hoses in each section. Since volumes of water associated with the washdown of equipment and floors are not controlled or reported, management is unaware of the impact of this use on the volumes of water utilised and volumes of effluent generated. Since the brewery floors and equipment should be clean and tidy, washdown is essential. However, the quality of the water used does not need to be of drinking water standard and recovered water, as suggested in Section 7.2, can therefore be used.

Other uses
Water brews are conducted before the start-up of production and the water leaving the vessels and lines is of sufficient quality to be utilised as, *inter alia*, rinse or washdown water.

As discussed in Section 6.2.2, water from the chilled liquor tanks is discharged to the drains when a temperature deviation occurs. This water should be transferred to a storage facility and utilised for other purposes including, *inter alia*, rinse or washdown.

A high volume of water is utilised as a coolant by the ammonia condensers each week. This water does not come into physical contact with the ammonia and is of a relatively high quality. It is recommended to investigate the development of a system where the water vapour is recaptured, condensed and reused within the cycle.

7.3 THE DEVELOPMENT OF AN INTEGRATED WATER RECOVERY SYSTEM

As seen thus far, each section within the brewery has the potential to optimise its water usage. However, the installation of many small storage facilities with associated piping will have high cost implications. Therefore an integrated approach to water minimisation should be taken. In conclusion, it is recommended that all opportunities to minimise water usage in a section should be identified and a centralised water collection point be developed where water with the potential to be reused can be stored. This will involve developing a water network within the brewery collecting water from the areas where the major losses occur. The quality of this water should be analysed and its use for washdown or other purposes investigated.

CHAPTER 8

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